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LEVEL

SOME GUIDELINES FOR EFFECTIVE TASK DESIGN IN COMMAND AND CONTROL SIMULATIONS

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Research Institute for the Behavioral and Social Sciences

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This report develops principles of task design for interactive simulations in which staff players execute the command and control of a simulated battle. A companion report on the design of simulations of command and control processes presents the basic design framework of a battle simulation capable of application alternatively to research, development, or training. This framework includes consideration of alternative configurations of the "player" staff modules so that an investigator may select a configuration best suited to his behavioral research objectives. The guidelines for effective task design are developed from the alternative configuration

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SOME GUIDELINES FOR EFFECTIVE TASK DESIGN IN COMMAND AND CONTROL SIMULATIONS

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SOME GUIDELINES FOR EFFECTIVE TASK DESIGN IN COMMAND AND CONTROL SIMULATIONS

BRIEF

This volume reports on the follow-on, Phase 2, research effort on the design of an Integrated Division-Level Battle Simulation for Research, Development, and Training. It develops the logical framework for simulated staff processing as a basis for developing guidelines for the design and implementation of player tasks in an interactive simulation. It examines the independent and interactive effects of the staff system being emulated (manual or ADP-assisted), staff module configuration, communication media within the staff module, and experimental purpose of task assignment. On the assumption that a specific staff system is being emulated and that a complete SOP for that system is available, procedures are then developed for adding to or modifying those procedures as required to insure that the required variables are controlled or are measurable. The material covered in this and a companion volume, "On the Design of Simulations of Command and Control Processes," is essentially identical except for Section 5.

Requirement:

Prepare a report discussing principles of task design for interactive simulations, including trade-offs among task realism, credibility, and impact on performance measurement, and providing guidelines for effective task design. In the light of the design problem in Phase 1 which gave rise to this task, it may be thought of as finding answers to the following questions:

- What are the principles of task design for interactive simulations?
- What are the trade-offs among task realism, credibility, and impact on performance measurement?
- Do they provide guidelines for effective task design?

This research effort was carried out in parallel with a second effort whose purpose was to develop a logical framework for simulated staff processing that can accommodate variant human performance from the team players in populated staff modules as well as simulated variant performance in simulated modules. It was also to determine whether alternative interface locations (between live players and the simulation) are feasible. The successful accomplishment of both tasks required search of largely common data sources and both required development of the detailed logical information flow structure within the staff modules that comprise the decision making node in military command control systems. Therefore, the technical approach to both

consisted of five steps of which the first four were common to both efforts. The five steps for the effort which is the subject of this report were:

1. A literature search covering human behavior in command control decision nodes and of extant games and simulations was conducted.

2. A detailed formulation of the staff processing required to process all message traffic postulated in the Phase 1 design was developed. This analysis began by defining the elementary operations performed by a single man--the basic building blocks of staff procedures. The sequence in which these elementary operations need be performed to process the message types selected in Phase 1 was established in the form of event thread charts.

3. The points of occurrence of variant human performance, i.e., of the error classes identified in Step 1 were identified. The frequency of occurrence was estimated since no hard data on error frequency were available.

4. A logical framework was then established for the design of simulated staff modules to permit such simulated modules to accommodate variations in human behavior in populated modules and reflect the effects of human errors in battle outcomes. Similarly, the framework was established to insert variant performance (errors) into the processing performed in simulated modules so that the reaction to such performance by populated modules could be observed and measured.

5. The purpose of the staff system and the nature of staff decision making were examined. The interactions between the staff system being emulated, simulation design and configuration, the internal communication within the staff module, and the purpose of the experiment are developed and their impact on experimental design and performance measurement is defined. The contents and level of detail of the Standing Operating Procedure (SOP) required to emulate a specified staff system are listed. Based on the assumption that such an SOP is available or has been developed, a set of procedures is then developed for formulating task design based on the configuration and class of experiment.

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INTRODUCTION

1.0 PURPOSE AND SCOPE

The results of the follow-on, Phase 2 effort on the design of an Integrated Division-Level Battle Simulation for Research, Development, and Training are contained in two companion volumes:

- <u>On the Design of Simulations of Command and Control Processes</u>
- <u>Some Guidelines for Effective Task Design in Command and Control Simulations</u>

Although based on the logic of the original Phase 1 top-down design[1], they transcend the original work in that they develop basic considerations that apply to the design of any simulation of command and control and to the design of player tasks in such simulations when used as experimental tools.

The Phase 2 effort has centered on two additional design requirements that were acknowledged, but not fully addressed, during the Phase 1 design work. These requirements can be stated as follows:

TASKS (KEY WORDS)	BASIS
1. Prepare a report:	
• Detailing the critical dimensions and parameters of human performance in command and control	• Search of behavioral science and gaming literature
• Providing a design for simulations of command and control processes	• Analysis of existing interactive simulations (to include design developed in Phase 1)
2. Prepare a report:	
• Discussing principles of task design for interactive simulations	• Search of behavioral science and gaming literature

[1] Tiede, R. V., Burt, R. A. and Bean, T. T., <u>Design of an Integrated Division-Level Battle Simulation for Research, Development, and Training</u>, (Army Research Institute Draft Technical Report, August 1979)

including trade-offs among task realism, credibility, and impact upon performance measurement

- Providing guidelines for effective task design

- Analysis of existing interactive simulations (to include design developed in Phase 1)

In the light of the design problems in Phase 1 which gave rise to these tasks, they may be thought of as finding answers to the following questions:

- <u>Variant (Non-Standard) Human Staff Performance</u>

  --Can the simulated staff modules be designed so that they will accommodate variant human performance on the part of one or more populated staff modules? This will allow behavioral scientists investigators to examine the effect of human staff errors on battle outcome.

  --Can the simulated staff modules themselves be made to generate common staff errors? This will allow examination for corrective responses that might be instituted by the populated modules.

- <u>Controllable Interface Boundaries</u>

  --Is it feasible, in the interest of economy of operations and player motivation, to vary the interface boundaries of the staff modules? This will allow the controller/investigator, in some experiments, to eliminate certain repetitive, low-skill procedural tasks (e.g., answering radios or telephones, transmitting messages, routine filing, etc.) from the live staff procedures.

- <u>Task Design for Interactive Simulations</u>

  --What are the principles of task design for interactive simulations? What are the trade-offs among task realism, credibility, and impact on performance measurement, and do they provide guidelines for effective task design?

These problems require the detailing of the relevant dimensions and parameters of human performance in command and control as well as a

more detailed design of the staff procedures to be established for the players in populated modules or, correspondingly, to be represented in simulated modules.

The report identifies three classifications of human errors that can occur during the processing of staff actions and therefore lead to the Blue force failing to accomplish its assigned mission. The human error types are based on a search of behavioral science and war gaming literature and an analysis of the event sequence relationships in the Phase 1 design. The latter analysis included the definitions of 27 "elementary operations" (for live staff players) or Class 1 events (for simulated modules). All staff procedures are composed from these basic procedural steps.

In this framework, the report addresses the basic design problems described above. With respect to the first problem, it shows that simulated staff processing can be designed in such a manner that simulated modules "accept and pass on" faulty or substandard staff actions generated by one or more populated staff sections, thereby allowing the substandard performance to be reflected in the battle outcome. The simulated modules can also be made to exhibit staff errors themselves, based on stochastic or fixed switches preset by the experimenter(s).

The second and third problems, that of controllable interface boundaries, and the discussion on the principles of task design under the enhanced basic design concept, are added as Section 5 of the two respective reports on this effort.

1.1 RELATIONSHIP TO THE PHASE 1 DESIGN

The Phase 1 design consisted of two parts: (1) the basic design concept for the Integrated Division-Level Battle Simulation and (2) a proposed initial implementation of the concept. The basic design concept was for a general interactive simulation model with sufficient scope and flexibility that it could be applied alternatively to behavioral research, to the development and evaluation of new tactics, or to the training of staff personnel. The system contained six "plug-in" modules, each of which could either be "played" by human players or else be simulated by means of rules imposed by the computer and/or controllers. Five of these modules represented the Blue Command Group and its four principal staff sections; the sixth module was the Red Command. The system provided for the play of a division-level (alternatively corps-level) war game in which the "configuration of play" could be selected beforehand. The configuration of play is the particular combination of populated modules and simulated modules chosen among the six. The play itself involved not only the simulated combat between the opposing forces but also the varying states of knowledge the opposing commanders use as the basis

for their tactical decisions. The system handled the information flow of approximately seventy-five standard tactical messages, and was based on an event-oriented simulation using approximately 350 separately defined events. These events covered staff actions, staff coordination, staff output, and staff input as well as the simulated battle occurrences.

The second part, the proposed implementation of the concept, developed a physical layout, the system architecture, the software requirements, and precise specification of the controller functions for the initial implementation. These key elements imposed three specific constraints on the scope of the full concept:

- One or two human controllers, aided by computerized preprocessing capabilities and an interactive executive control routine, would control the play of the game.

- Configurations of play would be limited to no more than two populated staff modules (any two out of six modules).

- Blue staff modules would operate under a manual staff system only.

This report now addresses the two additional design requirements in a manner that is consistent in all respects with the structural concept of Part 1. The enhanced basic design concept presented here, on the other hand, requires that the proposed initial implementation in Part 2 be modified.

1.2 TECHNICAL APPROACH

The technical approach used in the Phase 2 design work was based on a common point of departure for the two separate design requirements. The common basis consisted of a literature search for relevant background information and an analysis of existing interactive simulations, including the Phase 1 design itself. The approach consisted of the following six steps in which the first four were the common prerequisites to the last two:

- Step 1 - Literature search covering human behavior in command and control and interactive war game simulations.

- Step 2 - Detailed formulation of the staff processing required in the framework of the tactical message specified in the Phase 1 design.

- Step 3 - Identification of the points of occurrence and frequency of occurrence of variant human performance in the staff processing.

- Step 4 - Development of the logical framework for simulated staff processing so that the model design can accommodate variant human performance from the team players in populated modules as well as simulated variant performance in simulated modules.

- Step 5 - Examination of the staff processing structure to determine whether alternative interface locations are feasible, considering task realism, performance measurement requirements, and model implementation.

- Step 6 - Consideration of the special requirements for task design imposed by the use of such simulations as experimental tools.

1.3 ORGANIZATION OF THE REPORT

Section 2 presents the results of the review of the behavioral science and war gaming literature. The review was conducted in order to identify: the critical dimensions of human performance in command and control, the parameters describing the variance in such human performance, and the way existing simulations reflect the variance. Based upon the review, the essential operations that must be performed in information processing and decision-making were identified, although measurements of variance were sparse. Error analyses were found to be highly situation-oriented and consequently did not lend themselves to this effort. As a result three classes of errors were defined solely for the purposes of relating variant staff performance to battle outcome in the model.

Section 3 then defines the elementary staff operations that must be performed in command and control systems. These operations are based in part on the material identified in Section 2. The required staff processes, categorized solely from the tactical information messages set forth in the Phase 1 design, are then developed using event thread charts to link the elementary staff operations in appropriate event sequences. The section is concluded with a matrix showing the procedural step points at which the three classes of human error can occur.

Section 4 addresses the first design requirement by providing a logical design framework for accommodating variant human performance in the overall model design. The discussion begins by tracing the

tactical information flow in the model as a whole, then refines this flow by incorporating details of the staff procedures developed in Section 3 and by showing where human errors are involved in the flow cycle. The logical design for simulated staff processing is then developed from this framework. The implied system overhead associated with the enhanced design is also discussed.

Section 5 of the volume entitled On the Design or Simulations of Command and Control Processes discusses the feasibility of varying the interface boundaries of the staff modules to include trade-offs among task realism, credibility, and impact upon performance measurement.

Section 5 of the volume entitled Some Guidelines for Effective Task Design in Command and Control Simulations concludes with the principles of task design based on the overall model design with the new extensions.

SECTION 2

HUMAN PERFORMANCE IN COMMAND AND CONTROL

2.0 INTRODUCTION

This section reports on:

- The review of the behavioral science literature to determine:
  - The critical dimensions of human performance in command and control, i.e., the kinds of errors, omissions, delays, and invalidities introduced by human information processing and decision making.
  - The parameters describing the frequency, range, and distribution of such human performance as a function of environment, stress, form of data presentation, etc.
- The analysis of existing interactive and non-interactive simulations to determine how they:
  - Reflect variations in human performance in simulation outcomes.
  - Design tasks and procedures for information processing on a selective basis.

To assist in this determination, SAI reviewed an extensive quantity of behavioral science and gaming literature to ascertain the critical dimensions and parameters of human performance in command and control. The sought-after dimensions would describe the kinds of behavior (errors, omissions, delays, and invalidities) introduced by human information processing and decision making; these parameters would provide an initial basis for modeling the frequency, range, and distribution of these dimensions as a function of environment, stress, training, form of data presentation, etc. It was hoped that the review of existing interactive and non-interactive war gaming simulations would provide insight as to how previous models have reflected variance in human performance in simulation outcomes, and how tasks and procedures for information processing were designed on a selective basis.

2.1 REVIEW OF EXISTING WAR GAMING SIMULATIONS

Two primary sources [3,4] were reviewed to obtain a listing of all war gaming simulation models which might, even remotely, address C^3I functions. Table 2-1 contains a listing of each of these models, a summary description of each model's purpose and the model's proponent. Although each of the models have interesting aspects that would be of interest in the design of the battle outcome generator, only three - ADVICE II, FOURCE, and NETMAN - provide any real advancement in the modeling of human performance in combat simulation outcomes.

2.1.1 ADVICE-II[5]

The ADVICE-II model is a force-on-force, computer-assisted, division-level war game. The computer is used only to perform the time-consuming clerical, filing, computational and data retrieval tasks. Specifically, the computer keeps all records, maintains the data base, performs the numerical assessment, and generates all standard format reports to players.

The reports are delayed and the numerical content of the reports is degraded by means of stochastic routines with variable parameters that can reflect different information processing performance levels. In addition, information about enemy activity is stochastically degraded to reflect the performance of the intelligence system extension to the command and control elements.

3 Catalog of War Gaming and Military Simulation Models, Studies, Analysis, and Gaming Agency, Joint Chiefs of Staff, 8th Edition, January 1980

4 Tabulation of Models of Interest to CAA, Methodology, Resources and Computation Directorate, U.S. Army Concepts Analysis Agency, July 1979

5 Tiede, R. V., Leake, L. A., and Whipple, S. Jr., Information Flow and Combat Effectiveness, (Research Analysis Corporation, Report RAC-R-100, April 1970)

TABLE 2-1

CURRENT SIMULATION MODELS PERTINENT TO C^3I

MODEL (PROPONENT)	PURPOSE
Advice II (CACDA)	A computer-assisted division-level force-on-force war game which models the flow of tactical information in ground combat with realistic feedback to staff.
CAMMS (CATRADA)	A computer-assisted brigade-level training simulation used to train battalion and brigade command groups in the exercise of command and control.
CARMONETE/ATHELO (CAA)	A computerized, battalion level Monte Carlo, time-sequenced critical event simulation of a combined arms air/ground war game.
CEM IV (CAA)	A two-sided, fully automated, deterministic model capable of aggregating conventional warfare results as a series of four day theater level cycles.
COMMEL II.5 (CAA)	A computerized, analytical, general war battle model designed to process input data to develop a battle between division-sized forces.
CRM (DCA)	A computer-assisted, general war, analytical model which examines residual communications assets and the ability to restore interrupted users.

TABLE 2-1 (CONT'D)

CURRENT SIMULATION MODELS PERTINENT TO C^3I

MODEL (PROPONENT)	PURPOSE
CREST (CNO)	A computerized, analytical model that evaluates the effectiveness of one unit successfully evading one or more adversaries.
DADENS-C2 (ADS/DCD)	A computerized, analytical, general war and damage assessment/weapons effectiveness model designed to simulate either one- or two-sided war games.
DIVSIFT (SAI)	A computer model that measures the action handling effectiveness of a command post staff when the staff is loaded by the events of a combat scenario.
DIVWAG (CACDA)	A player-assisted, analytical, general division war model which performs the firepower, mobility, target acquisition, and combat service support functions.
FIRST BATTLE (CAC)	A low resolution battlefield simulation system designed to exercise division and corps staffs.
FOURCE (TRANSANA)	A division-level non-interactive force-on-force combat model with emphasis on the simulation of staff performance and combat information/intelligence flow.

TABLE 2-1 (CONT'D)

CURRENT SIMULATION MODELS PERTINENT TO C^3I

MODEL (PROPONENT)	PURPOSE
IDAHEX (OSD)	A computer-assisted, limited war, analytical and training model representing maneuver and its consequences.
MANMODEL (ARI)	A computer simulation of the data entry processes that focuses on system tasks and procedures in an effort to estimate performance as it pertains to data entry. By varying input parameters, MANMODEL permits system designers to explore the effects on the data entry process of changes in manning levels, training, personnel selection and other factors. It provides an evaluative vehicle for comparison of alternative system configurations, operational procedures and personnel characteristics (e.g., training, aptitude, motivation).
MATSS (SAI)	A dynamic computer simulation of target acquisition, attack decision, and attack processes against deeper targets that incorporates multi-sensor fusion and time delays.
NETMAN (ARI)	A computer model for simulating the information processing actions of army staff during field exercises using a computer-based message handling system.
NNWS (CNO)	A computer-assisted, analytical, limited war model of the interaction

TABLE 2-1 (CONT'D)

CURRENT SIMULATION MODELS PERTINENT TO C^3I

MODEL (PROPONENT)	PURPOSE
	and results of US/NATO Naval forces versus Soviet forces on a theater-wide basis.
NEWAIR (SHAPE)	A computer-assisted theater-level air battle simulation model which addresses the outcome of a conflict between air forces employing conventional weapons.
QUICK (SAGA)	A general war gaming system designed to assist the military war gaming analyst at the JCS level with the generation of detailed strategic nuclear war plans.
SIM II (CNO)	A computerized, analytical, limited war model of detailed and rigid naval warfare situations.
SIMTOS (ARI)	A computer-assisted simulation which permits laboratory research on tactical military decision making behavior, particularly with respect to information flow and display variables.
STAB II (NASC)	A computerized, analytical general war model used to analyze the effectiveness of airborne weapon systems.
STATE III (SHAPE)	A critical event, stochastic, computer-assisted land combat model for simulating armor/anti-armor engagements.

TABLE 2-1 (CONT'D)

CURRENT SIMULATION MODELS PERTINENT TO C^3I

MODEL (PROPONENT)	PURPOSE
STRAT MSG (USAF/SA)	A computerized analytical general war model which simulates the two-way flow of multi-priority messages between the NCA and forces.
TACOS II (ADS/DCD)	A computerized, analytical model designed to consider the effectiveness of ground/air defense and penetrating air forces.
WARRAMP-WCEM (CAA)	A computerized, analytical, limited war model of two forces while considering the effects of command and control, logistics and close air support.
WASGRAM (CNO)	An interactive, computer-assisted graphics model of naval warfare used for analysis and training.

The game is interactive with two players per side and three persons in the control group. The players are at division and brigade levels. Player-generated requests and orders are delayed but not degraded.

This model was the first to link command and control performance to battle outcome and is the basic concept which has been extended to fulfill the Phase 1 design effort. Variant human behavior is however simulated in highly aggregated form with insufficient resolution for the current purpose.

2.1.2 FOURCE[6]

FOURCE, or Command, Control, Communications, and Combat Effectiveness, is a division level force-on-force combat model with resolution to battalion. The simulation is a two-sided deterministic mathematical model which executes without player intervention. The purpose of the simulation is to evaluate and compare manual vs. ADP-assisted information processing within the division in terms of the battle outcome.

All of the operations and intelligence staffs within the division are simulated as either manual- or ADP-assisted. In the manual mode, time delays are introduced to reflect successive routing of messages through manual nodes. These time delays are eliminated, for the most part in simulated ADP-assisted staffs although querying times are considered. Time delays are computed as a function of processing times, workload for each staff element and communication delays. Processing times are dependent upon report type not report content. Errors are not introduced into the report content but occasionally a report is lost. Through this delay process, FOURCE has been able to distinguish between the actual battlefield and the battlefield as the staffs at various echelons perceive it.

Accordingly, FOURCE provides a significant contribution to the state-of-the-art in the modeling of command and control in combat simulations. However, the current effort extends the concepts developed for FOURCE in that it is interactive, provides for higher resolution and will model variant human behavior in aggregate form. FOURCE may be used to validate times, etc, but that is its only practical value.

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6 Command, Control, Communications and Combat Effectiveness Model Documentation, Technical Report Vol. II, TRASANA TM 3-78, October, 1978

2.1.3 NETMAN[7]

NETMAN is a non-interactive digital computer model which simulates the information processing actions of Army personnel during field exercises using a computer-based message handling system. The model does not link message handling effectiveness with battle outcome. However, it does place particular emphasis on certain human performance features considered to be important, e.g., operator stress, speed, precision, and level of aspiration. In simulating each operator, the model requires as input an estimation of time related data for various operator tasks to be accomplished. The overall man-machine performance measure, effectiveness, is calculated for a simulated exercise and summarized over the total exercise. It is composed of four independent factors -- thoroughness, completeness, accuracy, and responsiveness.

The relationships[8] that have been examined using NETMAN have particular relevance to this effort in the modeling of lower-order information processing, in that various message handling parameters are related to operator speed, and operator precision. These relationships will be particularly useful in defining and validating the parameters for lower-order processing functions.

2.2 REVIEW OF HUMAN PERFORMANCE IN COMMAND AND CONTROL

The review of the literature on human performance in command and control tasks or functions was essentially non-productive. Even though there is a prodigious amount of literature which addresses the many and varied ramifications of human performance, only a small segment of it is directly related to and in a form suitable for use in the design of simulations of command and control processes. Most of the relevant error analyses were highly specific studies of human performance in visual detections and graphic display applications, and

7 Siegel, A. I., Leaky, W. R., and Wolf, J. J., A Computer Model for Simulation of Message Processing in Military Exercise Control and Evaluation Systems, ARI Technical Report TR-77-A22, October 1977

8 Ibid.

during operation of input/output devices. The control factors being examined during these analyses were essentially related to the environment, stimuli or psychomotor skills. In addition, the data from these studies do not facilitate linkage to show interactions, sequential, or combined effects on combat outcomes. Another relevant discovery during the literature review was that error analyses were clustered around the lower skill level tasks in information processing functions while few research efforts focused on variance in the cognition or decision making processes. Accordingly, the literature did not provide detailed data on the critical dimensions of human performance in command and control nor did it provide appropriate parameters describing the frequency, etc, of such performance.

However, Gagne[9] did provide significant insight and assistance in developing the models for staff processing, whether simulated or populated. As shown in Phase 1, each staff process will be modeled via a sequence of exclusive events, each representing a discrete task or function that must be performed to complete the staff process.

Figure 2-1[10], provides a simplistic but very intuitive model of human functioning which has been used to extend our Phase 1 efforts to provide a clear and logical framework to link staff actions with the ongoing "battle" within the simulation. Gagne reviews human functions, within a system, as a sequence of transformations which the human being performs upon inputs to produce outputs. His model is directly relevant to our modeling efforts and can be extended to reflect the sequence of actions that occur within each staff module.

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9 Gagne, Robert M. and others, Psychological Principles in System Development, (New York: Holt, Rinehart and Winston, 1962).

10 Ibid, pg 54.

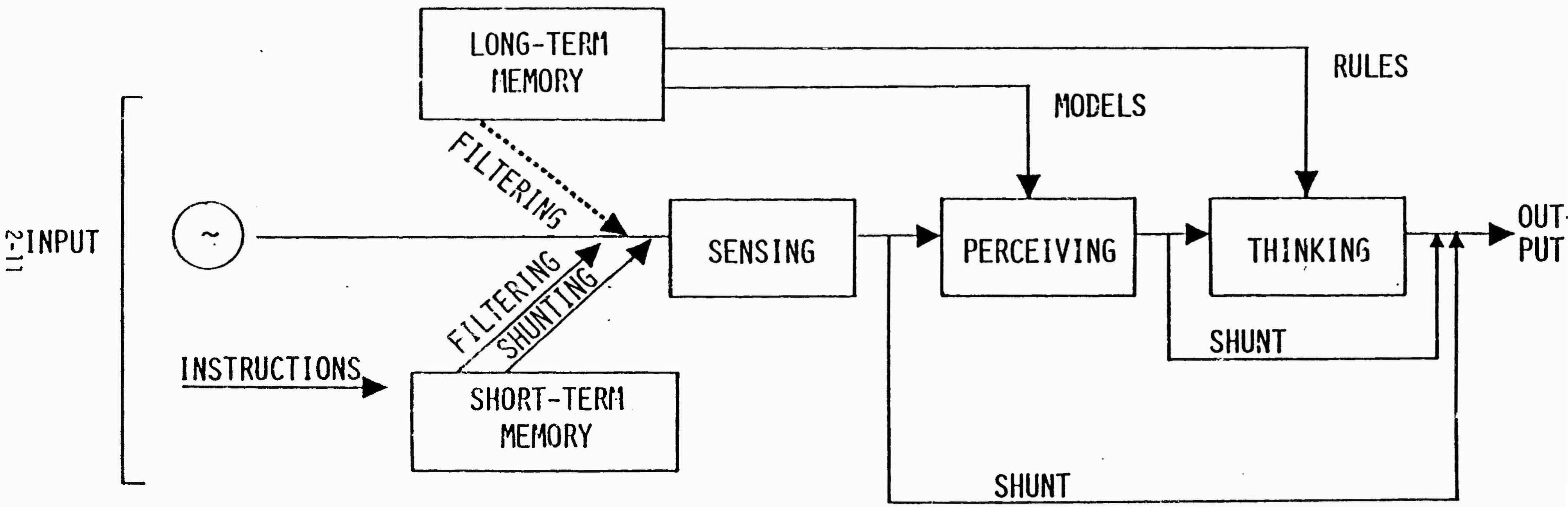

FIGURE 2-1. MODEL OF HUMAN FUNCTIONS*

* This figure appears in Gagne' (see footnote 9)

The input shown on the figure corresponds to the messages received by an individual section from all sources, while the instructions relate to the current operating procedure for that specific module. As described by Gagne, these instructions establish sets in short term memory which determine the shunting conditions and thus the level of functioning at which the individual operates in the situation. In addition, they establish the filtering conditions, which determine what the operator senses or attends to. As may be readily observed, this process is very similiar to the lower order information processing tasks inherently required of a division staff section. Finally, there are inputs to this process from long-term memory, the most important of which are the models, which make possible comparisons with inputs to produce perception, and the rules, which represent courses of action to be compared in the thinking process. The sequences in which these actions are accomplished are also stored in long-term memory.

The fundamental actions which are of primary interest are the sensing, perceiving, and thinking functions. According to Gagne,[11] sensing is a function which "indicates the presence or absence of a difference in physical energies". For our purpose this translates to the recognition of an incoming tactical message, whether delivered via voice, radio, telephone, hand, teletype or data link.

Filtering conditions establish attention to the method of receipt, while shunting conditions act to prevent the performance of higher-level functions by the human operator. Lower level tasks usually require operators to receive the information but not to interpret its meaning. Perceiving represents the next level in the sequence of actions. Here the individual operator produces outputs which, in effect, place inputs into categories whose basis is their effect rather than their appearance. In other words, perceiving is a matter of identifying the meaning of inputs. As before, instructions play their role as inputs for the establishment of shunting and filtering conditions. The most important inputs, however, are the models from long-term memory which provide standards against which inputs are compared. The last in the sequence of actions is thinking, the highest level of human functioning. To accomplish this function, an individual uses rules that are stored in long term memory to generate and select alternative courses of action in order to generate output or decisions. In many instances, the individual must transform the existing information or extrapolate beyond the boundaries of the existing information to produce an output, again based upon these models stored in long-term memory.

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11 Ibid, pg 45.

Gagne, through this intuitive mechanism, has represented a basic set of inferences that must be considered when observing the variety of behavior possible in a human being. We find this model interesting in that it provides a basic framework for examining and isolating the human activities in the system environment.

2.2.1 Critical Dimensions in Human Performance

J. S. Kidd's contribution[12] to Gagne's book provides additional definition to the model in terms of those critical dimensions that affect system effectiveness. Kidd has examined the operator in complex systems for the purpose of identifying which of his characteristics are germane to the system peformance. The framework he used also involved the specification of the operator's role or function in the system. In a complex information-processing system, Kidd has portioned these functions into two categories --**information-processing** and **decision-making**. The latter category should be conceived as being highly dependent upon the first; that is, the quality of the decision-making is dependent upon the quality of the information processes. Kidd has defined functions that belong to each category and these definitions have been used to fully define each elementary operation required in the simulation of the division staff sections. These functions are arbitrary and are not intended to describe completely all tasks assigned to human operations within an information-processing system.

A summary definition of each category and the functions included with each is presented below:

- Information-Processing. A series of actions or operations involving the communication or reception of data.

  - Signal Detection and Classification. Detection is a matter of distinguishing signal inputs, while classification is a matter of distinguishing among inputs.

  - Recoding. The translation from signals in one format to signals in another.

  - Accumulating and Summarizing. The collection and manipulation of quantitative and qualitative data to keep abreast of the status of subordinate units.

12 Ibid, pgs 159-183

- Output-Processing. The classifying, encoding, and accumulation of generated signals or information.

- Value Weighting and Destination Routing. The determination of the importance and destination of information to be disseminated.

- Decision-Making. The action of producing a choice or judgement from one or more alternatives based upon available information.

  - Selection and Synthesis. The interpretation of the content of the input to include the operator's experience with respect to the consistency and veracity of alternative sources.

  - Pattern Construction. Creating a coherent whole out of discrete fragments.

  - Cause-and-Effect Attribution. The assumption or determination of why the situation is at it appears.

  - Time-line Analysis and Prediction. The correlation of cause-attribution with the evaluation of time-contingent processes in the environment to extrapolate to possible outcomes.

  - Critical-Cause Selection. The determination of what factvors in the environment can be manipulated and the prioritization of these factors. This leads to the critical factor that must be manipulated to most directly achieve desired goals.

  - Action Selection. The selection of a course of action from available alternatives to achieve desired goals.

- Effect Evaluation. The assessment of action selection upon the environment based upon feedback subsequent to action initiation.

The above functions, then, define the critical dimensions associated with human performance in a command and control or information-processing system. These critical dimensions and Gagne's model provide the basic framework from which elementary operations have been defined and sequentially linked to encompass all those categories of action that must be completed within a staff section. Section 3.1 fully addresses this modeling effort.

2.2.2 Classes of Human Errors in Information Processing Systems

During the review of the literature, there was one reoccurring theme - to err is human. Errors are an expected human phenomenon and the research emphasis is on studying error causing factors in various combinations to determine ways in which to minimize their occurrence or effects.

For the purposes of this effort, the factors and the frequency with which they adversely impact human performance was of interest. The literature revealed that errors may be introduced by any number of factors, but the frequency with which they occurred was usually related to specific situations. The net result was that the factors that caused errors and the frequency with which they occurred were not available in a form relevant to the modeling of variant human behavior.*

This result led to an examination of how errors impact upon the division outcome. This impact can be partitioned into three categories:

- The body of information on which the commander and his staff base their execution of the assigned mission, is, or becomes, wrong or misleading.
- The commander and his staff fail to issue the correct orders in a timely manner even with adequate resources and an adequate body of information.
- The commander and his staff issue incorrect orders even with adequate resources and an adequate body of information.

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* However, a significant portion of these data will be helpful in the design implementation, e.g., ADP formats, data base entry, etc.

These three categories can be directly attributed to human errors on the part of the commander and his staff and readily lend themselves to correlation with three fundamental reasons for their occurrence. Specifically, the first category is brought about in part by the cumulative human errors in the way in which the body of knowledge is achieved and maintained, i.e., errors that cause the body of information on which decision-makers base their execution to become wrong or misleading. The second is mostly attributable to human errors in management; i.e., errors that lead to untimely execution of decisions, even if the body of information is correct. The latter category is solely attributable to human errors on the part of the decision-maker, i.e., errors that lead to the wrong decisions, even if the decisions are timely and based upon correct information.

This reasoning has led to the definition of three classes of human error in information processing systems:

- Data errors - those errors that introduce erroneous or misleading data into the data stream and/or the staff files/displays, e.g., the location of the 2/84 Mech Inf is plotted incorrectly on the G3 SITMAP on the wrong side of the WEGER R.

- Procedural errors - those errors that delay the completion of the staff action by making a false start or an error in performance of an elementary operation,e.g., G2 fails to coordinate with G3 and assigns a recce mission to the cavalry squadron unaware that the squadron has been assigned a screening mission in another sector, thereby delaying arrival of cavalry squadron.

- Cognition errors - those errors that cause a faulty tactical decision because of false or incomplete perception of the available data or because of inadequate action-selection criteria, e.g., the commander misinterprets an enemy feint as the main effort and commits his reserve prematurely.

As defined above, data and procedure errors are directly observable and measurable. This is true since the information stream/body of knowledge contains a reference standard from which to observe or measure deviations from ground truth or standard operating procedures. Cognition errors, on the other hand, are not directly observable and measurable because cognitive processes either alter existing information or generate new information, hence, there is no reference standard for comparison. This is discussed in detail in Tiede's[13] discussion of performance measurement in military information systems.

It is readily observed that these three classes of errors are defined to be mutually exclusive. This is a desired characteristic which allows the distribution of error phenomena over staff processing of information but this does not imply that each class of error has unique impact on the battle outcome. On the contrary, they may have similar impacts within a very wide range. For example, either a transposition of UTM coordinates (data error) or a faulty pattern recognition (cognition error) may lead to an erroneous prediction of an enemy breakthrough. The point is that the impact of these errors is highly situation dependent and the impact upon the battle outcome may not be traceable to the originating class except under highly controlled experimental conditions.

2.3 CONCLUSIONS ON HUMAN PERFORMANCE

2.3.1 Existing War Gaming Simulations

Surprisingly, there was only one war gaming simulation (FOURCE) which explicity simulated human performance in command and control and then linked the performance with the battle outcome. However, computerized decision rules within FOURCE are simplistic. Another model (NETMAN) transformed the effects of fatigue, stress, proficiency, etc, into time-delays in the decision-making process, but these delays were not related to the battle outcome nor were the

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13
Tiede, R. V. On the Analysis of Ground Combat, p. 62 (MA/AH Publishing, 1979)

various effects related to the quality of the decision. The one remaining model that has applicability was ADVICE II. This simulation models human performance for the lower level information processes in highly aggregated form and employs live players to make the higher level decisions. Since it is an interactive system, the battle outcome reflects both the timeliness and quality of the decision process.

Each of these models provides insight into the design of the integrated division-level battle simulation. However, the actual design will be extending the state-of-the-art of command and control and war gaming simulations by providing for interactive populated and simulated staff models and by linking and measuring the effects of variant human performance on the battle outcome.

2.3.2 Human Performance in Command and Control

Although the review of the behavioral science literature was essentially non-productive in terms of the objectives, it did provide a basic model for indicating the sequence and interaction of events within an information processing system and helped to specify the critical dimensions in information processing and decision making.

The lack of substantive data on the type and frequency of errors led to a determination of kinds of errors which impact upon the battle outcome. This in turn led to the definition of three classes of error--data, procedural, and cognition--which may be overlaid on the division-staff information processing functions to allow behavioral scientists to examine the effect of human staff errors on battle outcome.

SECTION 3

DELINEATION OF STAFF PROCEDURES

3.0 INTRODUCTION

This section presents an analysis of interactive simulations that focuses on the detailing of division staff procedures and identification of the procedural step points at which one or more human errors might occur. The analysis begins with the basic building blocks of the staff procedures, the elementary staff operations performed by one man. These fundamental procedural steps are identified, based in part on a suggested approach from another study. The detailing of the procedures, that is, the development of event thread charts composed from the basic building blocks, is, on the other hand, based solely on the set of tactical information messages already defined in the Phase 1 design. Seven such charts are presented showing the staff actions either as the Standing Operations Procedures (SOPs) to be followed by players in live staff modules or as the Class 1 event sequence in the simulated modules. The seven charts cover the 420 different staff processes stemming from the standard tactical messages. The section is concluded with a matrix showing the procedural step points at which the various classifications of human errors can occur. The error classifications are those from Section 2.

The analytical framework developed in this section is applied to the design of simulated staff modules in Section 4 which in turn forms the basis for the discussion of task assignments in Section 5.

3.1 ELEMENTARY STAFF OPERATIONS

The Phase 1 design combined, for the first time, command and control processes executed by human players in live staff modules with the simultaneous simulation of the same processes in other, but now simulated, staff modules. Depending on the selected configuration of play, simulation represented an interactive war game from the point of view of the populated modules and a simulation of decision-making processes from the point of view of the simulated staff modules. However, no documents were found in the literature which treated these more-or-less separate areas jointly. Earlier efforts and other

studies have provided ideas and approaches for the design of an interactive war game. Similarly, but in a different vein, alternative approaches to the simulation of decision-making processes have yielded some insights into the problem of simulating human staff performance. Consequently, the material here, which identifies the elementary staff operations common to both the live staff procedures and the computer logic for simulating staff processes, is largely unexplored territory.

The concept of elementary operations originated in an earlier study[1] of staff processes. This study used an event-oriented simulation of the staff actions to determine the sequence of operations, the time required for each step, the time spent in queue, the staff member who performed each operation, and the station at which each operation was performed. The approach involved breaking staff processes down into a series of elementary operations such as those listed in Table 3-1. The study itself provided some insights into human staff performance, but the simulation did not address the actual tactical information content of the staff actions being processed.

A similar approach has been adopted here but this time it has been extended to include the information content. The staff processes invoked by the standard tactical messages in the Phase 1 design have been broken down into a series of elementary staff operations, where each such operation is performed by one man. Furthermore, in order to provide a basis for the task design for interactive simulations, each elementary operation identified has an associated process/skill level required of the man who performs the operation. These levels were affixed by the following argument:

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1 Tiede, R.V., Walker,M. E., Stenstrom,D. J., and Sweeny, S. O. The Integrated Battlefield Control System (IBCS) Third Refinement Study, (McLean, Va., Science Applications, Inc.: Final Report, March 1975)

TABLE 3-1. ELEMENTARY OPERATIONS

THROUGHPUT OPERATIONS

Receive Radio (Rcv Rad): All action steps required to produce a written copy of an incoming message via radio to include required radio operating procedures.

Receive Telephone (Rcv TP): All action steps required to produce a written copy of an incoming message via telephone to include required telephone operating procedures.

Receive RATT (Rcv RATT): All action steps required to produce a written copy of an incoming message via RATT to include required RATT operating procedures.

Receive Aurally (Rcv Aur): Reduction of an oral transmission to a written form.

Transmit Orally (Xmit Oral): All action steps required to convey a written message by unaided, human voice to a predesignated addressee(s).

Plot on Map (Plot): Post or update symbols on map.

Enter in Journal (Enter): Physical process of recording in journal, workbook or list.

Retrieve (Rtrv): (Must be associated with a specific file or display.) Locating and extracting from a particular file or display.

Compose: Prepare a draft of a product or portion of a product.

Make Overlay (Overlay): Physical preparation of map overlay.

Post Display (Post): Enter or update data on visual display.

BRANCHING OPERATIONS

Determine Internal Routing (DIR): Read for content and select addressee/station routing within element for further processing of that product.

TABLE 3-1. ELEMENTARY OPERATIONS (CONT'D)

Determine External Routing (DER): Read for content and select external addressee(s).

Reproduce, Manual (Repro, Man): Production of an exact handwritten copy (may be multiple copies using carbon paper).

Reproduce, Machine (Repro, Mach): Production of an exact copy (or copies) utilizing copy machine.

Type: Production of an exact copy using a typewriter. (May be multiple copies using carbon paper.)

COLLECTION OPERATIONS

Consolidate and Approve (C&A): Accept, integrate, edit portions of a product produced by more than one source and release final product for distribution (normally to external addressees). The same operation is used for approval only in which case there is a single input.

TERMINATING OPERATIONS

File: (Must be associated with a specific station.) To place a product or extract therefrom in a designated, closed (nondisplay) storage place or to update a permanent (nondisplay) record.

Terminate (Term): This copy goes no further and is placed in File 13 or convenience file.

Transmit Radio (Xmit Rad): All action steps required to convey a written message via radio to a predesignated addressee to include required radio operating procedures.

Transmit Telephone (Xmit TP): All action steps required to convey a written message via telephone to a predesignated addressee to include required telephone operating procedures.

Transmit RATT (Xmit RATT): All action steps required to convey a written message via RATT to a predesignated addressee to include required RATT operating procedures.

Transmit Courier (Xmit Cour): Picking up an action from an outbox, courier, other staff member, or self and delivering it to a predetermined addressee/station or his inbox.

"Figure 3-1 is a representation of a series of processes such as a decision node carries out on information flowing through the node. At the bottom of the figure is an external information stream--the communications network--which the node taps and to which it contributes. Six progressively more complex processing levels are depicted. The information that flows up from the external stream must first be received, a Level I or communications process. The received information in a tactical military system is in the form of orders (plans), summaries, reports, queries, or requests. These must be tagged, sorted, recorded (think of the large number of telephone and voice radio inputs), and used to update files; much of it is also displayed on situation maps or totes. The composite of these processes may be called Level II or message center and filing processes. The Level II processes produce a data base, some part of which is in the form of visible displays for ready reference. It is pertinent to comment in passing that the graphical representation of certain kinds of information on a situation map is the substitute for the hill overlooking the battlefield and for helicopters when the latter cannot fly or see."[2]

"The next four process levels use the files in successively more complex ways. Note that they, too, update the files, but these updates are more in the nature of manipulations on the basic data added by Level II. These utilization processes begin with Level III, selective retrieval of information from the files. At Level IV, such data are aggregated by means of a priori rules, which may vary from simple arithmetic combinations to more sophisticated rules of combination such as the appearance of three or four maneuver battalions operating in the same area triggers the search for their associated fire and service support elements. The important consideration is that the rules for aggregation have been determined in advance and are stored. Process Level V also aggregates data, but the rules for aggregation are devised by the user in real time--that is, he hypothesizes, through pattern recognition, new and higher level interpretations of the data being presented. For example, the rapid increase in density of artillery in a given sector is interpreted as an indicator of enemy intent to attempt a breakthrough in that sector. Process Level V may also be accomplished in a succession of stages that amounts to piling hypotheses one on top of another. Furthermore,

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2 Tiede, R. V., On The Analyis Of Ground Combat, (Military Affairs/Aerospace Historian Publishing, 1978).

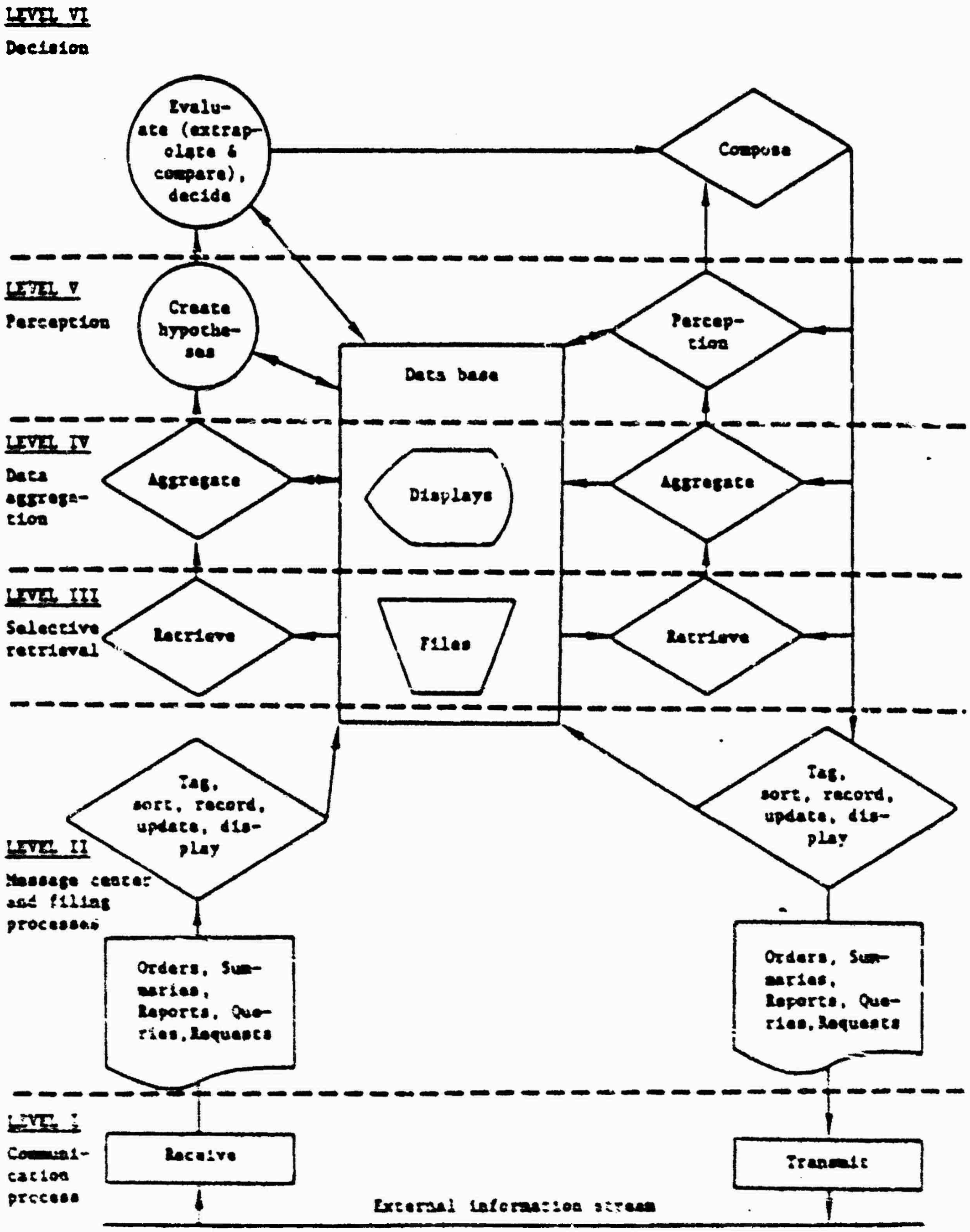

FIGURE 3-1. PROCESS LEVELS IN A TACTICAL DECISION-MAKING NODE*

* Taken from Tiede (see footnote 2)

data aggregations may be extrapolated forward in time. This amounts to yet another hypothesis formulation of a different type; assumptions are made about observed rates and/or accelerations. For example, examination of present positions and rates of advance for both sides leads to a prediction that the main battle will occur at point Y at time T. Level V produces what is commonly called perception. At the highest level, Level VI, data aggregations are compared and evaluated, and one or more are selected. This last is the culmination of the decision process."[3]

3.1.1 Definitions of the Elementary Operations

The elementary staff operations for the division-level battle simulation are presented in Table 3-2. The staff procedures to be followed by players in populated modules are structured out of these 27 basic procedural steps. Correspondingly, the event threads in the computer simulation of staff processes are composed from these Class 1 events.

The elementary operations fall into two broad groups in a manner suggest by J. S. Kidd[4]. According to Kidd, the tasks allocated to human operators within a general man-machine system fall into the two categories of **information-processing** and **decision-making.** While the line of demarcation between the two categories is somewhat obscure and arbitrary, the table groups the elementary operations of Levels I, II, III and IV in the information-processing category and those at the higher levels under decision-making. Furthermore, under these categories, the individual definitions contain italicized references to Kidd's task descriptions, where applicable.*

In this table and the discussion following, the short word "chops" is used to mean request for concurrence.

One point should be made about the dual purpose table. The elementary operations defined are ordinarily understood to be one-man tasks whether they are interpreted as procedural steps in a live staff

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3 Ibid.

4 Gagne Robert M., and others, Psychological Principles in System Development (New York: Holt, Rinehart, and Winston, 1962.)

* Kidd's task descriptions were oriented to radar man-machine systems. It is remarkable that the same task descriptions are applicable to corpo- or division-level command and control systems.

TABLE 3-2

DEFINITIONS OF THE ELEMENTARY OPERATIONS

E.O. DESCRIPTOR	PROCESS/SKILL LEVEL	DEFINITION
Information-Processing		
INITIATE BY CLOCK	I	Start a staff action whose output is due at a prescribed clock time by SOP. *Signal Detection and Classification.*
RECEIVE (or ACCEPT)	I	RECEIVE: transform oral communications received by radio or telephone into a hand written message, making one or more copies at the time. ACCEPT (subsumed under RECEIVE): accept a hand written/printed message delivered by a courier. *Signal Detection and Classification.*
TRANSMIT (or DELIVER)	I	TRANSMIT: transform a hand written message into oral communications on a radio or telephone. DELIVER (subsumed under TRANSMIT): hand over a written message to a courier or hand carry the message to its addressee. *Output-Processing.*
DER1	II	Determine the external routing of a received message. "External" means outside the staff section including other staff sections, Corps and adjacent headquarters, but not subordinate units in the BOG. *Value Weighting and Destination Routing.*
DER2	II	Determine the external routing for information copies of a message generated/processed in the staff section. In this case "external" means outside the staff section, including other

		staff sections, Corps and adjacent headquarters as well as subordinate units in the BOG. *Output-Processing.*
DIR1	II	Determine the precedence for message processing and the internal routing for the purpose of updating the staff files/displays. *Value Weighting and Destination Routing.*
DIR2	II	Determine the internal routing for generated/processed messages for the purpose of filing/posting output reports. *Output-Processing.*
ENTER	II	Log in the receipt/transmittal of a message. *Accumulating and Summarizing.*
FILE	II	Place a received/generated message, or elements thereof, in the appropriate staff file. *Accumulating and Summarizing.*
MAKE COPIES	II	Reproduce copies of a written message, as required.
COMPOSE	III	Prepare in draft or final form an output query, report, or frag order based on the action selection made by the decision-maker. *Output-Processing.*
DECOMPOSE	III	Extract from a received message data elements relevant to the functions of the staff section. *Recoding.*
DETERMINE COGNIZANCE	III	Determine the area of responsibility for the action selection made by the decision-maker. The subsequent processing of the action should be switched if the area of responsibliiy is outside the purview of the staff section. *Output-Processing.*

POST (or PLOT)	III	POST: transfer oral or written data onto a graphic display or status board. PLOT (subsumed under POST): transfer onto a scaled situation map. *Recoding.*
RETRIEVE	III	Withdraw a received/generated message from its appropriate staff file. *Output-Processing.*
COORDINATE W. STAFF	IV	Determine whether the action selection made by the decision-maker should be approved by the Commander and/or coordinated with other staff sections prior to its release. Subsequent processing of the action should be switched if approval or co-ordination is determined to be required. *Action Selection.*
COORDINATION COMPLETE?	IV	Determine whether concurring responses have been received from all sections to which chops requests were submitted. *Effect Evaluation.*
<u>Decision-Making</u>		
EVALUATE IN CONTEXT	V	Determine whether the received message generates the requirement for formal staff action at this time. The determination may be based on the message content alone or on a trigger criteria existing for certain type messages. If formal staff action is determined not to be required at this time, the action processing terminates. *Selection and Synthesis.*
INITIATE BY SELF	V	Initiate formal staff action based on perception of situation or problem held in the mind of the initiator. *Selection and Synthesis.*

TABLE 3-2 (CONT'D)

SYNTHESIZE DATA	V	Generate from the available data a picture or perception of the situation or problem. *Selection and Synthesis.*
EVALUATE DATA	V	Determine whether: (1) the uncertainties of the perception warrant the pursuit of more information before proceeding with the action; (2) the perception warrants immediate action; or (3) the perception warrants both of the above. *Effect Evaluation.*
CONSTRUCT PATTERN	V	Complete the picture or pattern by hypothesizing the missing or unknown elements. *Pattern Construction.*
EXTRAPOLATE SITUATION	V	Interpret the situation by extrapolating the time relationships inherent in the perception. *Time-line Analysis and Prediction.*
GENERATE ALTERNATIVES	V	Postulate two or more alternative courses of action which address the analyzed situation or pattern. *Cause-and-effect attribution* and *Time-line Analysis and Prediction.*
ESTABLISH CRITERIA	VI	Formulate the weighting factors to be used in comparing the alternative courses of action. *Critical Cause Selection.*
EVALUATE ALTERNATIVES	VI	Rank the alternative courses of action by applying the weighting factors. *Critical Cause Selection.*
SELECT ACTION	VI	Select the best course of action from the postulated alternatives. If no more than one alternative has been generated, the selection is entirely automatic. *Action Selection.*

module or as Class 1 events in a computer simulation of the staff processing. The strict interpretation as one-man tasks, however,breaks down in the case of two Level V operations: EVALUATE IN CONTEXT and SYNTHESIZE DATA. In a live staff module, these procedural steps will ordinarily be performed by the senior staff officer himself. But both operations call for accessing tactical information from the staff section files/displays in order to evaluate the received message in context or to generate a picture or perception of the situation. The senior officer in a live module may request assistance in these accessing subtasks from other subordinate staff players. Consequently, the one-man task rule breaks down in the live staff procedures.

Consider as an example the staff processing that would take place if the G3 were to receive a chop request from G2 regarding the proposed use of air cavalry helicopters for a post-strike damage survey. It will be shown in the next subsection that the G3, under these circumstances, would perform the following sequence of operations preparatory to responding to G2: SYNTHESIZE DATA, EVALUATE DATA, CONSTRUCT PATTERN, EXTRAPOLATE SITUATION, GENERATE ALTERNATIVES, EVALUATE ALTERNATIVES, and SELECT ACTION. The G3 would emerge from the last of these operations with the basic decision whether or not he concurred with the modified mission for the air cavalry elements. The sequence of operations, however, would begin with one of the Level V steps mentioned above. In a live G3 module, the senior operations officer might very well request the help of the assistant operations officer or the operations sergeant in assembling the information about the current status and missions of the air cavalry troop prior to his analyzing the situation. In this instance, it is clear that the SYNTHESIZE DATA step is not, strictly speaking, a one-man operation.

In a simulated staff module, on the other hand, the interpretation of the one-man operations will be followed in the strictest sense. The computer will simulate the staff processing of the receipt of a chops request like that above as though the elementary operations involved were each performed by a single individual. It will be shown in Section 4 that this rigid rule provides the basis for simulating the chance occurrences of human error phenomena in the staff processing.

3.1.2 Class 1 Events

The definitions of the elementary operations given in Table 3-2 provide a basis for completing the list of Class 1 events

specified in the Phase 1 design. In the general event-oriented simulation structure, Class 1 events were defined as the staff processing events the structured sequences of which gave the basic logic for simulated staff modules. The report stated that all the different event threads reflecting the staff processing would contain "an internal trigger, or starting, Class 1 event, and one or more terminating, or ending, Class 1 events. The number of events simulated between the trigger and terminating actions steps will depend on the individual action SOPs and on the level of detail used in simulating the staff action." The definition of the elementary operations now fix the level of detail, and the intermediate Class 1 events can be added to the original table (Table 4-3 in the Phase 1 report).

Table 3-3 shows the now complete list of Class 1 events in the basic design concept for the battle simulation. The event numbers shown in the Table are based on the convention adopted for that design. The following points should be noted about the Class 1 events:

- Event No. 100 corresponds to the elementary operation INITIATE BY CLOCK.
- Event Nos. 101 thru 112 are all variations of one elementary operation RECEIVE.
- Event Nos. 189 thru 199 are all variations of one elementary operation TRANSMIT.
- The remainder of the events in the table are, with one exception, in one-to-one correspondence with the remaining elementary operations in Table 3-2*.
- The one elementary operation for which no Class 1 event has been defined is INITIATE BY SELF. This exception is discussed further in Section 4.

It should be noted further that these Class 1 event definitions may be modified when the question of variable interface boundaries is addressed. As will be seen in the next subsection, one

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* The event numbers for these Class 1 Events are so chosen that they provide ready identification of the process/skill level associated with the elementary operation. Thus Event Nos. 121 thru 127 are Level II, Event Nos. 130 thru 134 Level III, etc.

TABLE 3-3. CLASS 1 EVENTS

EVENT NUMBER	DEFINITION OF THE EVENT
Internal Triggers	
100	Clock indicates that it is time to initiate staff action.
101	Receive a tactical information message from BOG or higher HQ.
102	Receive a retransmitted copy of input to another staff section.
103	Receive an info copy of output by another staff section.
104	Receive a query from another staff section.
105	Receive a request for concurrence from another staff section.
106	Receive a request for consideration from another staff section.
107	Receive a concurring response to a request for concurrence.
108	Receive a non-concurring response to a request for concurrence.
109	Receive a decision from the Commander.
110	Receive a non-concurring response to a request for consideration.
111	Receive a response to its query to another staff section.
112	Receive information from another staff section.
Action Steps	
121	Determine external routing of retransmittal copies (DER1).
122	Determine external routing of information copies of output (DER2).
123	Determine precedence for processing and internal routing for files/displays update (DIR1).
124	Determine internal routing for section copy update (DIR2).
125	Log in receipt/transmittal of all input/output messages. (ENTER).
126	Place received/generated message, or elements thereof, in appropriate section files (FILE).
127	Reproduce copies of a message (MAKE COPIES).

TABLE 3-3. (CONT'D)

Action Steps (Cont'd)

130	Prepare output message in draft or final form (COMPOSE).
131	Extract from received message selected data elements relevant to staff section function (DECOMPOSE).
132	Determine area of responsibility for the selected action (DETERMINE COGNIZANCE).
133	Transfer data onto a status board or graphic display (POST or PLOT).
134	Withdraw received/generated message from appropriate section files (RETRIEVE).
140	Determine requirements for Commander's approval or staff coordination (COORDINATE W. STAFF).
141	Determine whether concurring responses cover all staff sections solicited (COORDINATION COMPLETE?)
150	Determine if formal staff action required at this time (EVALUATE IN CONTEXT).
151	Generate perception. (SYNTHESIZE DATA).
152	Determine if more information required (EVALUATE DATA).
153	Complete pattern by hypothesizing the missing or unknown elements (CONSTRUCT PATTERN).
154	Interpret the situation by time-line extrapolation (EXTRAPOLATE SITUATION).
155	Postulate two or more courses of action (GENERATE ALTERNATIVES).
163	Formulate weighting factors for comparing alternatives (ESTABLISH CRITERIA).
164	Rank the alternatives by applying the weighting factors (EVALUATE ALTERNATIVES).
165	Select the course of action (SELECT ACTION).

Terminators

189	Send to selected staff elements.
190	Issue frag order or warning order.
191	Initiate query.
192	Initiate a request for concurrence.
193	Initiate a request for consideration.
194	Initiate a report for higher headquarters.
195	Aggregate information on file for a response.

Terminators (Cont'd)

196	Issue a concurring response to a request for concurrence.
197	Issue a non-concurring response to a request for concurrence.
198	Issue a non-concurring response to a request.
199	Retransmit copies of input.

approach to eliminating the low-level, repetitive staff operations is simply to combine the Level II, III and IV tasks in a staff action under the Level I trigger event or under the Level I terminating event associated with the action. This would mean that the live modules and simulated modules alike would be implemented by means of Class 1 Event Nos. 100 thru 112 as triggers and Event Nos. 189 thru 199 as terminators, but that these events would have broader definitions covering the Level II, III and IV steps involved. The sequences of Class 1 events spelling out the low-level events that could thus be eliminated are presented in the next subsection. The logical design implications are developed in the companion report, On the Design of Simulations of Command and Control Processes.

3.2 EVENT THREAD CHARTS FOR STAFF PROCESSING

The logical sequences of events that make up the simulated battle were presented in Design Note J of the Phase 1 design. Separate event thread charts were given for each standard tactical information message that was involved in the command and control of the Blue division-level forces. The charts were composed from the six classes of events that formed the basic structure of the model.

The event thread charts were necessarily incomplete in one respect. Although they showed the Class 1 trigger events that started the staff processing associated with a tactical information message and the Class 1 terminating events that ended the staff actions, they did not reflect the internal action steps between the starters and the terminators.

The elementary operations and/or Class 1 events set forth in the previous subsection now provide a basis for developing the complete event thread charts for the staff processing represented in simulated staff modules as well as the corresponding SOPs to be established for players in live staff modules. The charts serving these two parallel purposes are presented here.

3.2.1 Categorization of Staff Procedures

Within the spectrum of the standard tactical messages specified in the Phase 1 design, there are 405 different staff procedures involving unique input/output messages and unique staff sections. There are also 15 additional staff actions in which the senior officer in a staff section initiates formal staff action because he spontaneously perceives that it is required forthwith

(INITIATE BY SELF). The resulting 420 staff procedures provide the basis for the categorization of staff procedures and the event thread charts for staff processing.

The seven (7) categories of staff actions to which this family of 420 procedures reduced are shown in Table 3-4. The table shows that for each of seven (7) different kinds of actions--each identifiable by the manner with which it is triggered--there is a separate sequence of procedural steps (or Class 1 events) characterizing the staff processing. The trigger events are those listed in Table 3-3.

The event thread charts for the seven categories are presented in the following paragraphs.

3.2.1.1 Category 1 Actions

The first category of staff procedures covers all actions triggered by the receipt of a Class 4 input message from the BOG, or higher or adjacent headquarters. The event thread chart is shown in Figure 3-2.

This chart and the ones to follow are based on the event thread method of specifying the sequence of events and/or procedural steps involved in the simulation. The circles represent defined events. The arrows connecting successive events represent the passage of time. Here the events themselves contain the following identifying information:

- The Class 1 event number (from Table 3-3).
- The elementary operations descriptor from (Table 3-2).
- The process/skill level of the operation (also Table 3-2).

All charts are intended to serve two separate purposes. First, they specify the basic logical structure to be used in the simulated staff modules. Second, they give the staff action SOPs for player roles in

TABLE 3-4

STAFF ACTION CATEGORIES

Intersection of Tactical Information Messages and the Staff Modules

Category	Triggered By	No. Actions from Phase 1 Design
1	Receipt of external tactical message from BOG/Corps (Event No. 101)	33
2	Receipt of retransmitted copy of another section input (Event No. 102)	78
3	Receipt of action copy, info copy, query answer, and any response except a concurring chops response (Event Nos. 103, 106, 108, 110, or 111)	192
4	Internally initiated (INITIATE BY SELF)	15
5	Receipt of directive from Commander or concurring chops response (Event Nos. 107 or 109)	20
6	Initiated by clock/SOP (Event No. 100)	6
7	Receipt of staff query or request for chops (Event Nos. 104 or 105)	76
	TOTAL	420

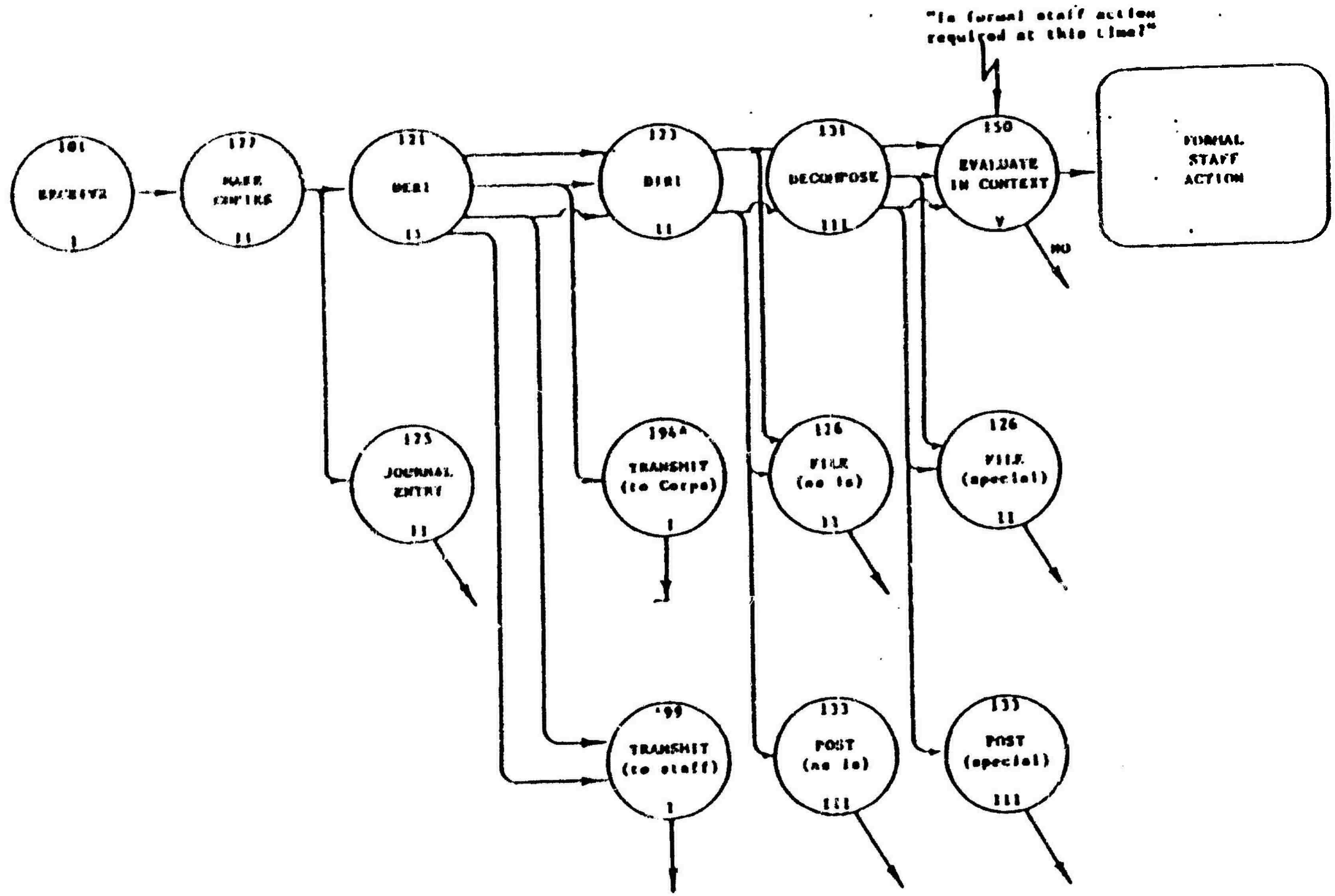

FIGURE 3-2. CATEGORY 1 ACTIONS

Triggered by Receipt of <u>External Tactical Messages</u> from BOG/CORPS

the populated modules. In the latter case the individual events are to be interpreted as individual procedural steps, i.e., elementary operations ordinarily performed by one member of the player team.

Figure 3-2 shows that Category 1 actions always culminate in a box labeled FORMAL STAFF ACTION. This box denotes a continued sequence of staff processing events whose thread chart is shown in Figure 3-3. The formal staff action segment is shown in a separate chart because it is common to several other staff procedure categories.

Formal staff action involves a number of elementary operations with Process/Skill Levels V, and VI. The segment can be thought of as the culminating staff processing that focuses on the tactical decision-making required of the staff element. In contrast to this, it should be noted from Figure 3-2 that the front half of Category 1 actions consist almost entirely of lower level operations associated with the maintenance and update of the section files and displays. The single exception is the procedural decision choice EVALUATE IN CONTEXT in which the senior staff officer determines whether formal staff action is required at this point in time.

3.2.1.2 Category 2 Actions

The second category of staff procedures covers all actions triggered by receipt of retransmitted copies of another staff element's input. The retransmission copies will always stem from the front end processing of Category 1 actions by another staff section. The Category 2 event thread chart is shown in Figure 3-4.

The front end processing of Category 2 actions clearly shows a different structure from that of the previous category. Special mention should be made, moreover, of the sequence of events stemming from the procedural decision choice EVALUATE IN CONTEXT shown in the chart. The added logical structure is included in order to accommodate one tactical information message among all those specified in the Phase 1 design. This message is the Post-Strike Analysis Report. Formal damage analysis is performed by the Fire Support Element following a strike, but the FSE is supplied with the raw data for his analysis through the receipt of retransmitted copies of Post-Strike Damage Reports sent to G2. Consequently, whenever FSE receives a (retransmitted) Post-Strike Damage Report, he must decide (in EVALUATE IN CONTEXT) whether the indivdual report provides the trigger criteria to begin the formal analysis. Furthermore, after he

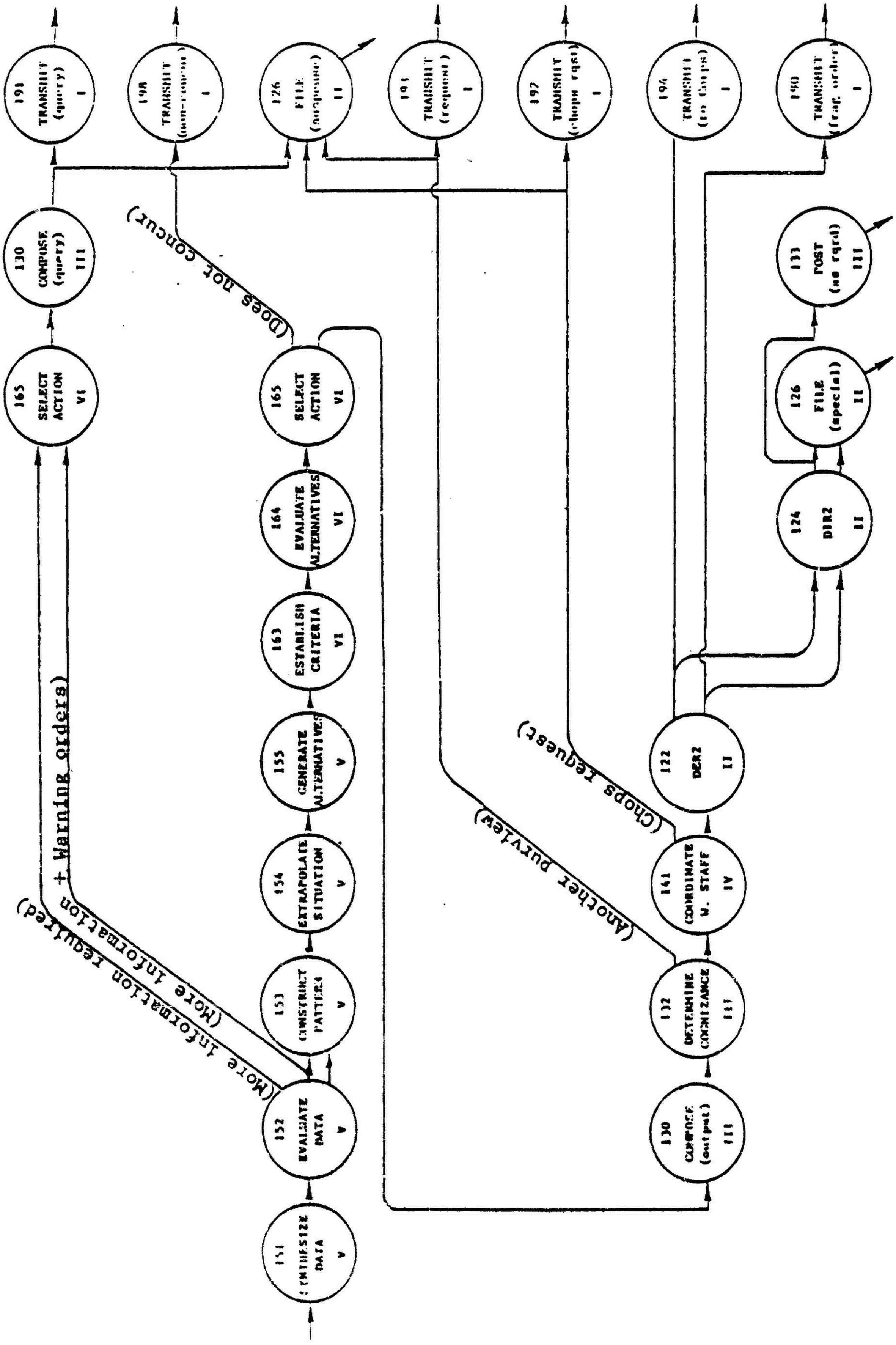

FIGURE 3-3. FORMAL STAFF ACTION SEGMENT

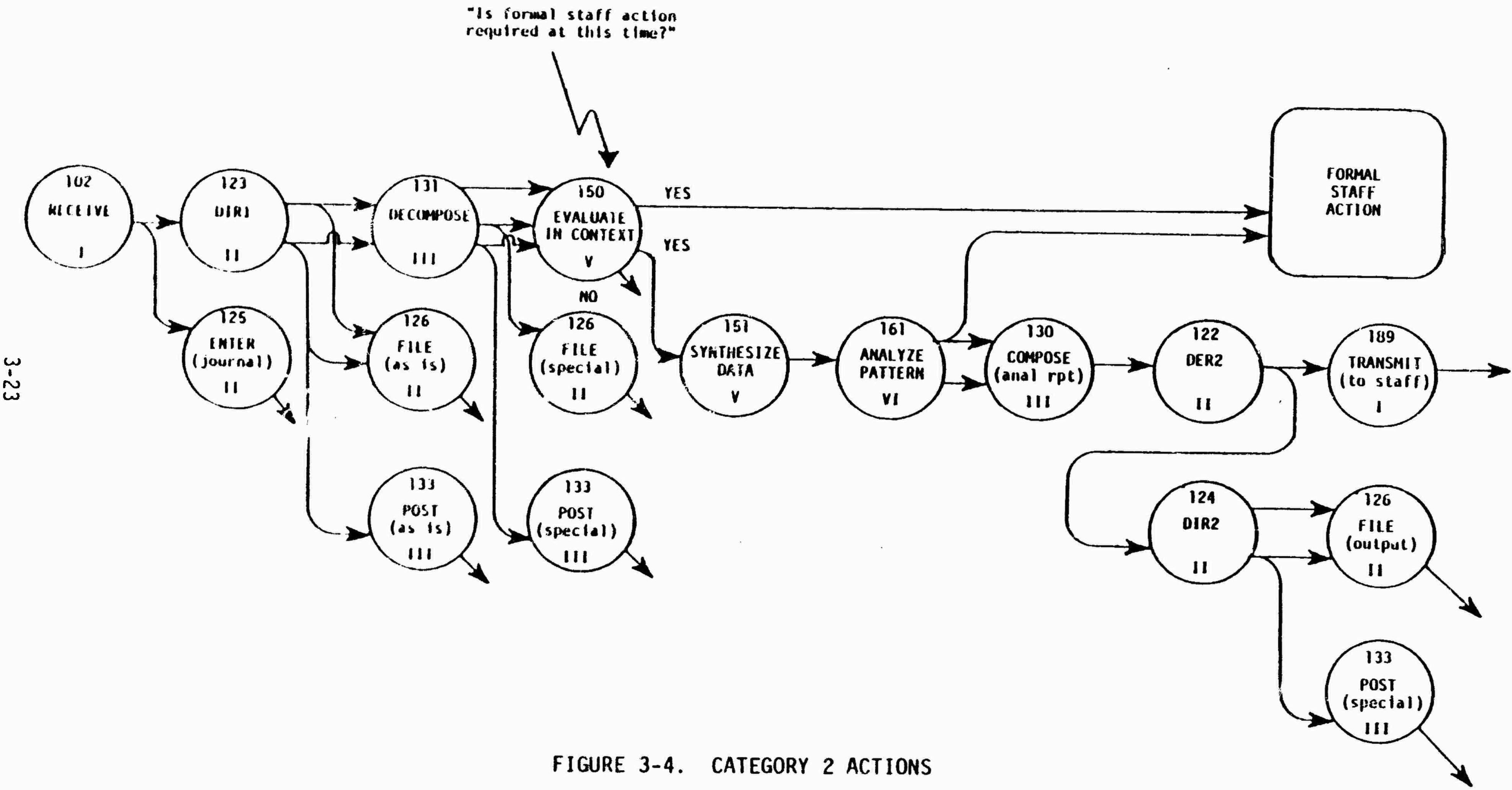

FIGURE 3-4. CATEGORY 2 ACTIONS

Triggered by Receipt of Retransmitted Copy of Another Staff Section Input

has embarked on the formal analysis, he may perceive that the results of the analysis not only must be sent to CG, G2 and G3, but also provide the basis for formal staff action with respect to the division artillery units. The added logical structure here in the Category 2 event thread chart is devoted solely to these processing requirements of the Post-Strike Analysis Report.

3.2.1.3 Category 3 Actions

The third category of staff procedures covers the largest group of actions identified in the Phase 1 design (see Table 3-4). The actions are those triggered by receipt of action copies, information copies, staff query responses, or responses to all requests except concurring chops responses. Category 3 actions cover the majority of staff coordination processes in the battle simulation. The event thread chart is shown in Figure 3-5.

The front end processing of Category 3 actions is somewhat simpler than that in the previous categories. Furthermore, it is anticipated that the frequency with which these actions will terminate in EVALUATE IN CONTEXT (hence, not continue on into formal staff action) will be higher than for Categories 1 and 2. The vast majority of these actions will simply be "paper mill" processing in which the staff section receives information copies of another section's output and no further disposition is indicated beyond the filing of the subject report.

3.2.1.4 Category 4 Actions

The fourth category of staff procedures cover those actions that are initiated by the senior staff officer because he holds a perception of the situation or problem in his mind and has determined that formal staff action should be instituted forthwith. The event thread chart is shown in Figure 3-6.

The interpretation of Category 4 staff procedures is clear enough for live staff modules. During the course of a division-level

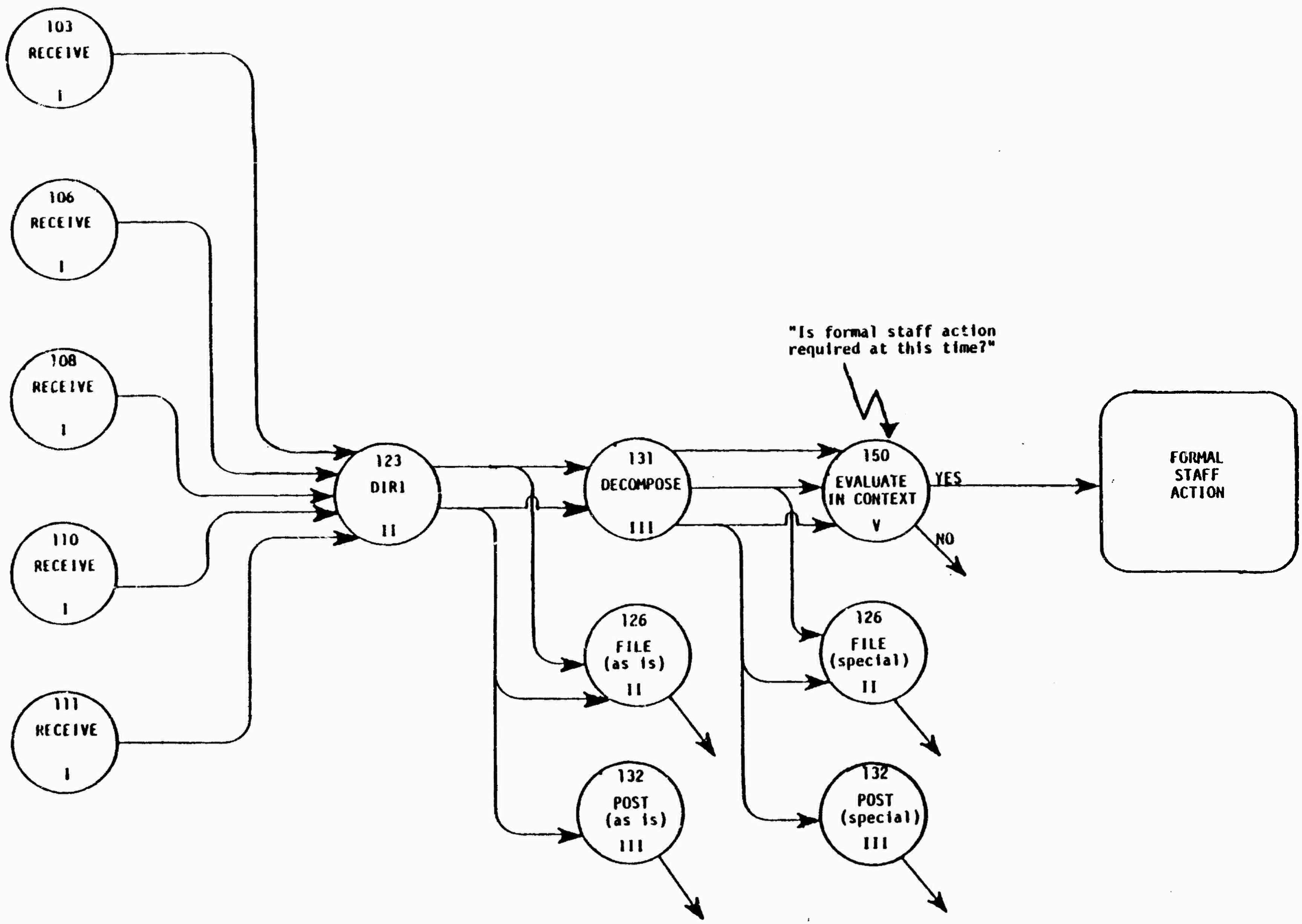

FIGURE 3-5. CATEGORY 3 ACTIONS

Triggered by receipt of staff <u>action copies</u>, <u>info copies</u>, <u>query answers</u>, and any <u>responses</u> except <u>concurring shops responses</u>.

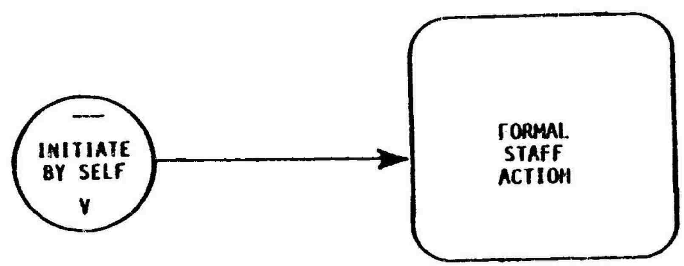

FIGURE 3-6. CATEGORY 4 ACTIONS
Internally Initiated Actions

combat, the Commander or any of his principal staff officers may spontaneously initiate formal staff action pertinent to the successful execution of the division's assigned mission. However, the computer simulation of internally initiated actions will necessarily fall short of modeling the human brain "when the light comes on." As stated in paragraph 3.1.2, the elementary operation INITIATE BY SELF has no corresponding Class 1 event definition. Class 1 events, as staff processing steps, were originally thought to be task performance steps carried out by a simulated staff person in response to some kind of external stimulus. In this case, "when the light comes on," the stimulus is internal. The Phase 1 concepts of Class 1 events and special "release" events (intervention by the controller(s)) do not, by themselves, provide sufficient framework for simulating internally initated actions. The actions will have to be simulated by programming them as externally triggered events.

The additional logical framework required for simulating Category 4 actions is presented in Section 4. There may very well be behavioral research experiments in which the simulated staff modules will be triggered to reflect internally initiated actions as part of the dynamic setting that is presented to the live player team.

3.2.1.5 Category 5 Actions

The fifth category of staff procedures covers those actions triggered by receipt of a directive from the Commander or a concurring chops response. The actions involve only a small number of output-processing tasks since the basic decisions on which their output frag orders or Corps requests are based will have been made in other, earlier staff actions. The event thread chart is shown in Figure 3-7.

For the processing of concurring chops responses, Category 5 staff procedures employ the decision-making step: COORDINATION COMPLETE? The procedural rule established by this elementary operation is that no frag order or Corps request for which chops requests have been sent out shall be released until concurring responses have been received from all sections solicited. If one or more chops requests are returned as non-concurring (and consequently processed as Category 3 actions), then it should be clear that the Category 5 processing of the concurring responses will terminate at the procedural choice: COORDINATION COMPLETE? and not culminate in the issuance of a frag order or Corps request.

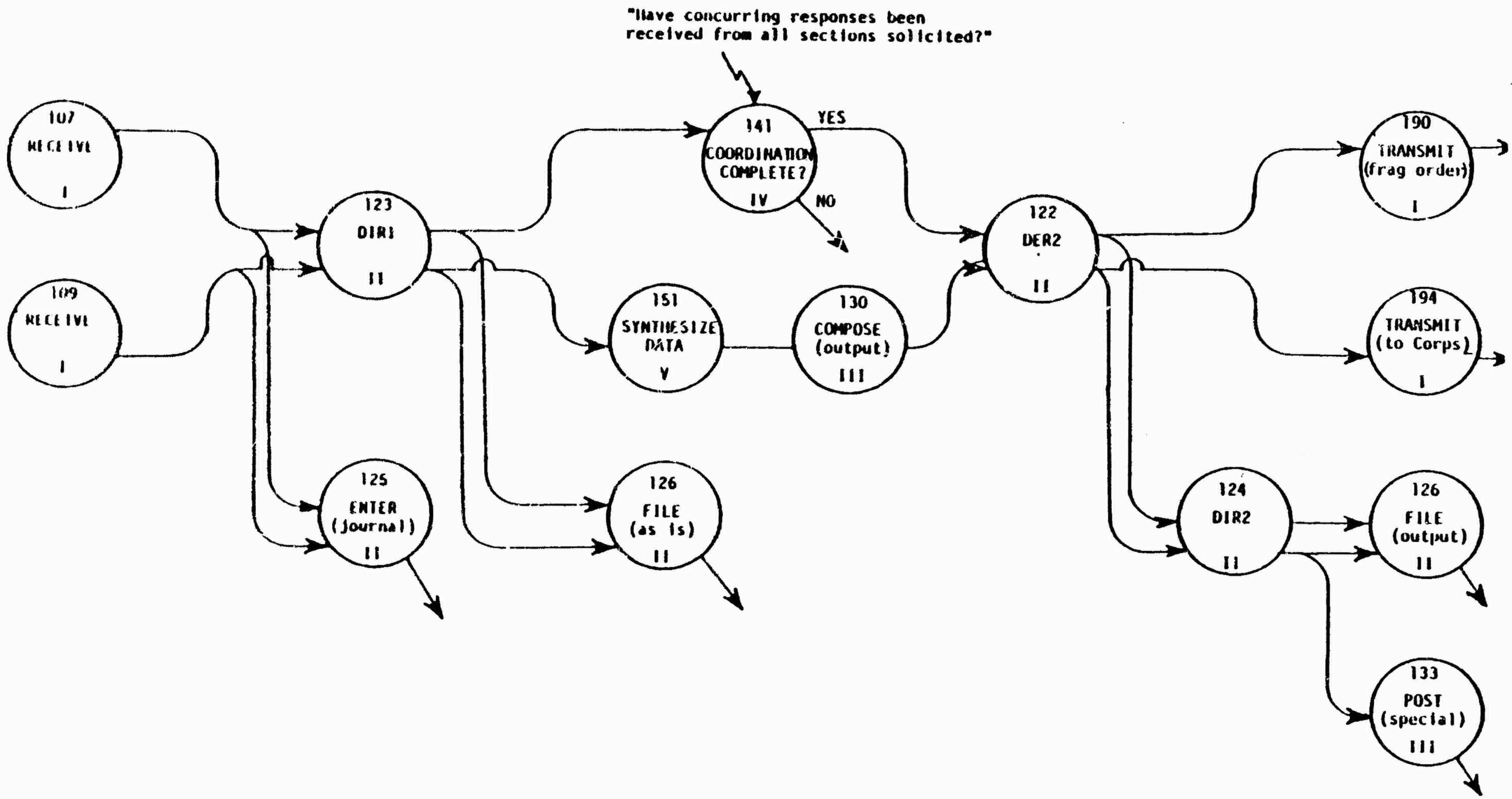

FIGURE 3-7. CATEGORY 5 ACTIONS

Triggered by Receipt of a Directive from the Commander or a Concurring Chops Response

It should be added that this feature of the Category 3 and Category 5 procedures provides the senior staff officer with several recourses if a proposed course of action "bounces" with one or more non-concurrences. Under the Category 3 procedures, he may reformulate the proposed course of action taking into account the objections raised by the other staff officers, or he may resubmit the original output but this time route it for the Commander's approval, notwithstanding the non-concurrences from the other sections.

3.2.1.6 Category 6 Actions

The sixth category of staff procedures pertains to the periodic reports to higher headquarters that must be prepared by the division staff. These actions are always triggered by the clock. At the appropriate time in advance of the due time, the staff section must embark on the report preparation tasks. The event thread chart is shown in Figure 3-8.

Category 6 procedures are applicable to the following six reports identified in the Phase 1 design:

- Division Situation Report, prepared by G3
- Division Intelligence Summary, prepared by G2
- Intelligence Paragraph of the Division SITREP, prepared by G2
- Preplanned Request For Fire Support, prepared by FSE
- Division Personnel Daily Summary, prepared by G1/G4
- Division Logistics Report, prepared by G1/G4

It can be seen in the figure that the first step in Category 6 procedures is the operation SYNTHESIZE DATA in which the senior staff officer assembles the tactical information necessary for the composition of the report. The data are compiled from the section files/displays. In accordance with the definition of this elementary operation (Table 3-2), if the required information is found to be

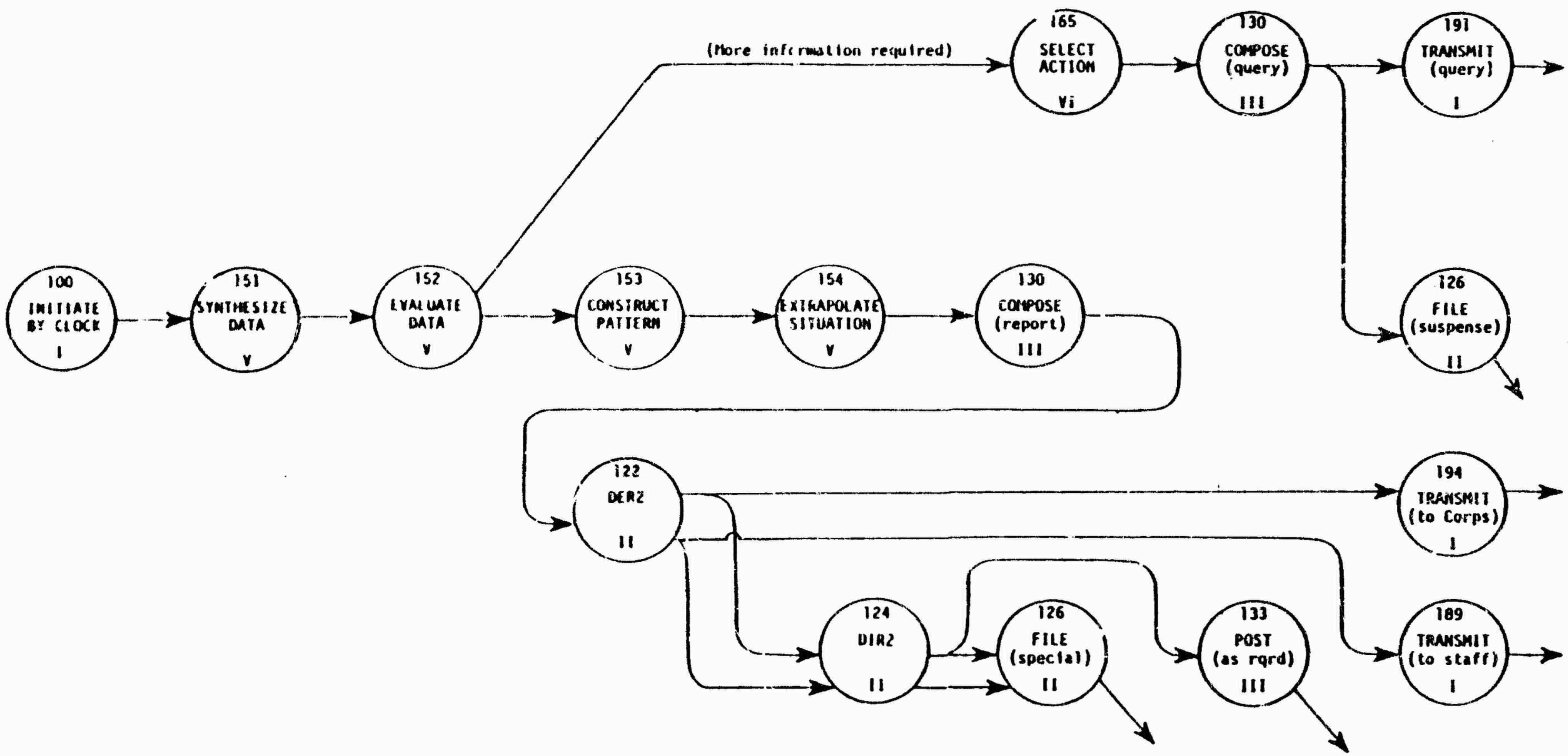

FIGURE 3-8. CATEGORY 6 ACTIONS
Initiated by the Clock and SOP

incomplete, the subsequent processing of the report preparation must be switched in the same manner as that shown in the formal staff action segment (Figure 3-3). For example, if the G3 finds, in preparing the Division SITREP, that the G2 has failed to submit the Intelligence Paragraph, then he (the G3) cannot proceed with his analysis and report composition but instead must first send off a staff query to G2. This type of "contingent procedural switching" will be shown to be a significant aspect of aberrant human performance in Section 4.

3.2.1.7 Category 7 Actions

The last category of staff procedures covers the staff actions attendant upon receipt of a query from another section or a request for concurrence on a proposed course of action. The event thread chart is shown in Figure 3-9.

In the staff processing of queries, the Category 7 procedures exhibit another example of contingent procedural switching as discussed above. According to the Phase 1 design, staff queries are limited to requests for the latest version of certain Class 3 or Class 4 reports, copies of which are kept on file in the section having cognizance for the type report. The G2, for example, will keep on file the latest copies of the Wx Forecast, Bde Intsums, Estimate of Enemy Strength, Composite Target List (Intel), Division Intsum, and the Intel Paragraph of the Division SITREP that he has received or generated. At any time he may receive a staff query from another staff section. The query will specify one of these reports, and in order to respond to the query, the G2 must withdraw the appropriate copy from his files (RETRIEVE) and send it off to the section who submitted the query.

Now, in the framework of the example described above, suppose the G2 receives a query from G3 specifying the current Intelligence Paragraph. The G3 submitted the query because he had found (in the Category 6 procedure) that he could not compile the Division SITREP because the G2 had failed to supply the Intelligence Paragraph. The G2 (now in the Category 7 procedure) would discover upon attempting to retrieve the aforesaid report from his files that the material was not there because he had failed to generate it in the first place. As a consequence of this discovery, the G2 would be required to switch away from the normal query response sequence and to start in immediately on the compilation and composition of the overdue report. This second example of contingency procedural switching suggests even more

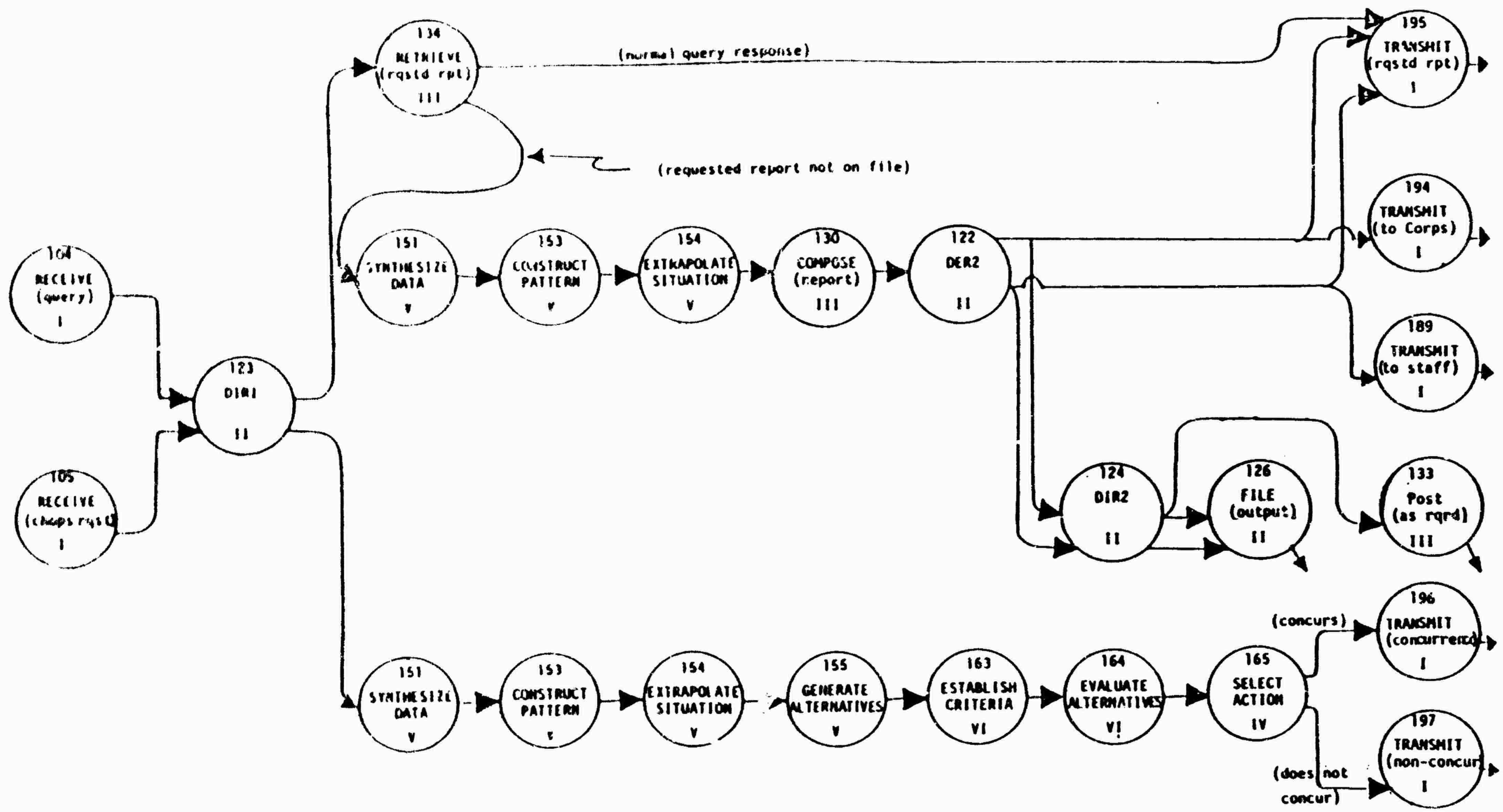

FIGURE 3-9. CATEGORY 7 ACTIONS

Triggered by Receipt of a Staff Query or a Request for Concurrence

strongly the significance of substandard human staff performance in behavioral research experiments.

3.2.2 Preliminary Discussion of Variable Interface Boundaries

The seven event thread charts presented above provide the second tier of building blocks with which the logical structuring of simulated modules may be approached. The charts also provide a visible basis for addressing the second design requirement, which is the elimination of some of the low-level, repetitive processing tasks for the live modules. One approach to this requirement is to build in the capability for changing the interface boundaries between the staff modules and the rest of the computer simulation. A conceptual picture of these boundaries is shown in Figure 3-10, which is taken from the Phase 1 design[5]. The annular ring in the figure represents the five Blue staff modules. The unshaded module (G2) is populated with human players; the remaining, shaded modules are, under the illustrated configuration of play, simulated modules. Within this annular ring, the staff processing of the tactical information will be governed by the staff procedures specified by the seven event thread charts. The populated module, in this case G2, will perform its "play" according to the action SOPs given by the charts. The simulated modules will represent the staff processing by means of the sequence of Class 1 events given in the charts.

In this framework, the input interface, which is denoted by the arrows pointing into the annular ring, corresponds to the left hand margins of each of the seven staff processing charts. The data transfer into the staff modules is always followed by the elementary operation RECEIVE. Similarly, the output interface, which is denoted by the arrows coming out of the annular ring, corresponds to the implicit data transfer following the elementary operation TRANSMIT. Although there are several isolated occurrences where the terminating TRANSMIT operation appears in the middle of the charts, most TRANSMIT events appear at the right hand margins.

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5 Tiede, R. V., Burt, R. A. and Bean, T. T., Design of an Integrated Division-Level Battle Simulation for Research, Development, and Training, (Army Research Institute Draft Technical Report, August 1979).

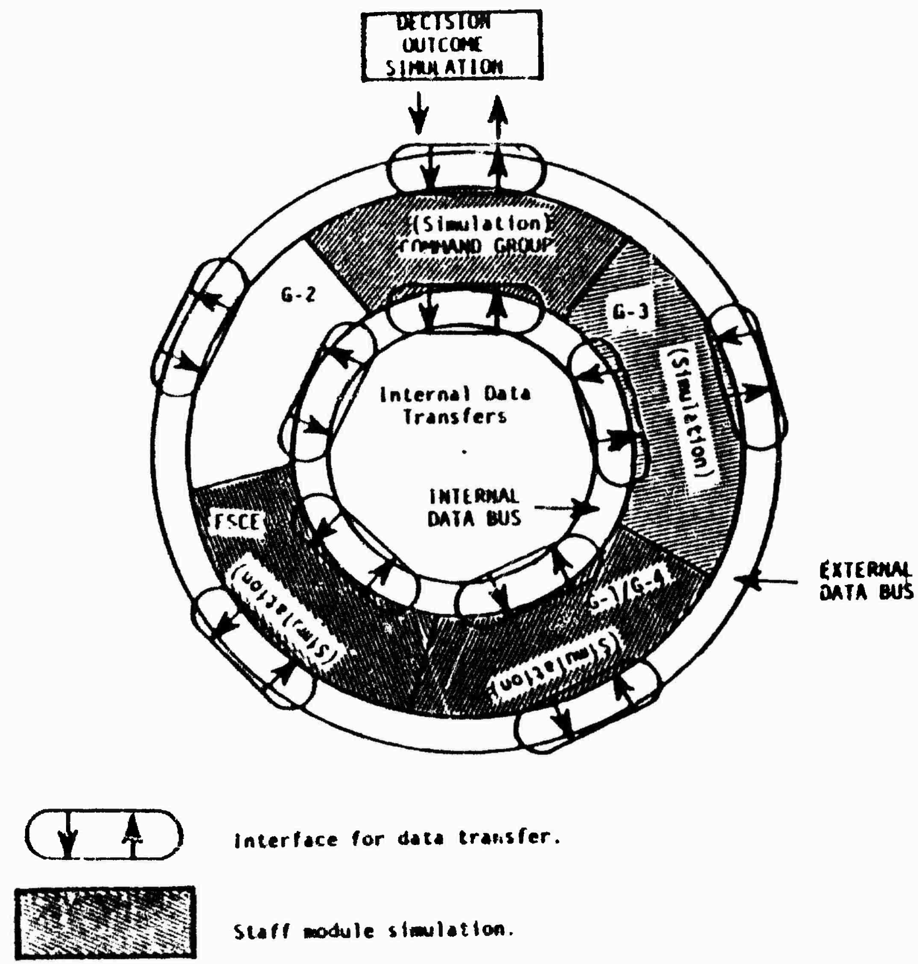

FIGURE 3-10. DATA FLOW IN MODULAR STAFF SIMULATION

The interface boundaries, specified in this manner, spell out the full range of procedural steps or Class 1 events that is required in the staff processing by a division-level staff. The steps include all the low-level, repetitive information processing tasks that, for some behavioral research investigations, may represent so much excess baggage in terms of the objectives of the experiments.

The discussion that follows introduces the idea of changing the interface boundaries. In order to show the implications of a relocated boundary, an extreme position has been selected for the relocation. The selected position is oriented to a live staff module consisting of only one player: the senior staff officer and decision-maker. If the battle simulation can be developed so that it can allow the play of one-man live staff modules based on this extreme boundary location, then other, intermediate boundary positions between the two extremes appear entirely feasible.

The proposed boundary for a one-man populated module is now illustrated using the charts for Category 1 Actions. Figures 3-11 and 3-12 show the input interface and the output interface locations if the staff processing for a live module were to begin at the point where the decision-maker determines whether formal staff action is required at this time (in EVALUATE IN CONTEXT) and end at the point where he effects the implementation of his selected course of action (in COMPOSE, SELECT ACTION, or COORDINATE W. STAFF). The data transfer from computer to player or from the player back to the computer would take place at these points.

Similar interface boundary locations can be generated in the remaining event thread charts. However, it can be seen from these figures by themselves that the new, extreme positions eliminate nearly all the Level I, II, III and IV elementary operations from the procedures to be followed by the one-man live staff modules. In this conceptual framework, all the information processing at the beginning of the staff action and all output processing following the tactical decision will be simulated in the computer. The lone player in the live staff module must address only the fundamental decision-making procedural steps which, with one or two exceptions, are all Level V or VI operations.

This approach to providing variable interface boundaries brings out the central design problem that is addressed in the companion volume, _On the Design of Simulations of Command and Control Processes_. The original Phase I concept included the Blue perceived

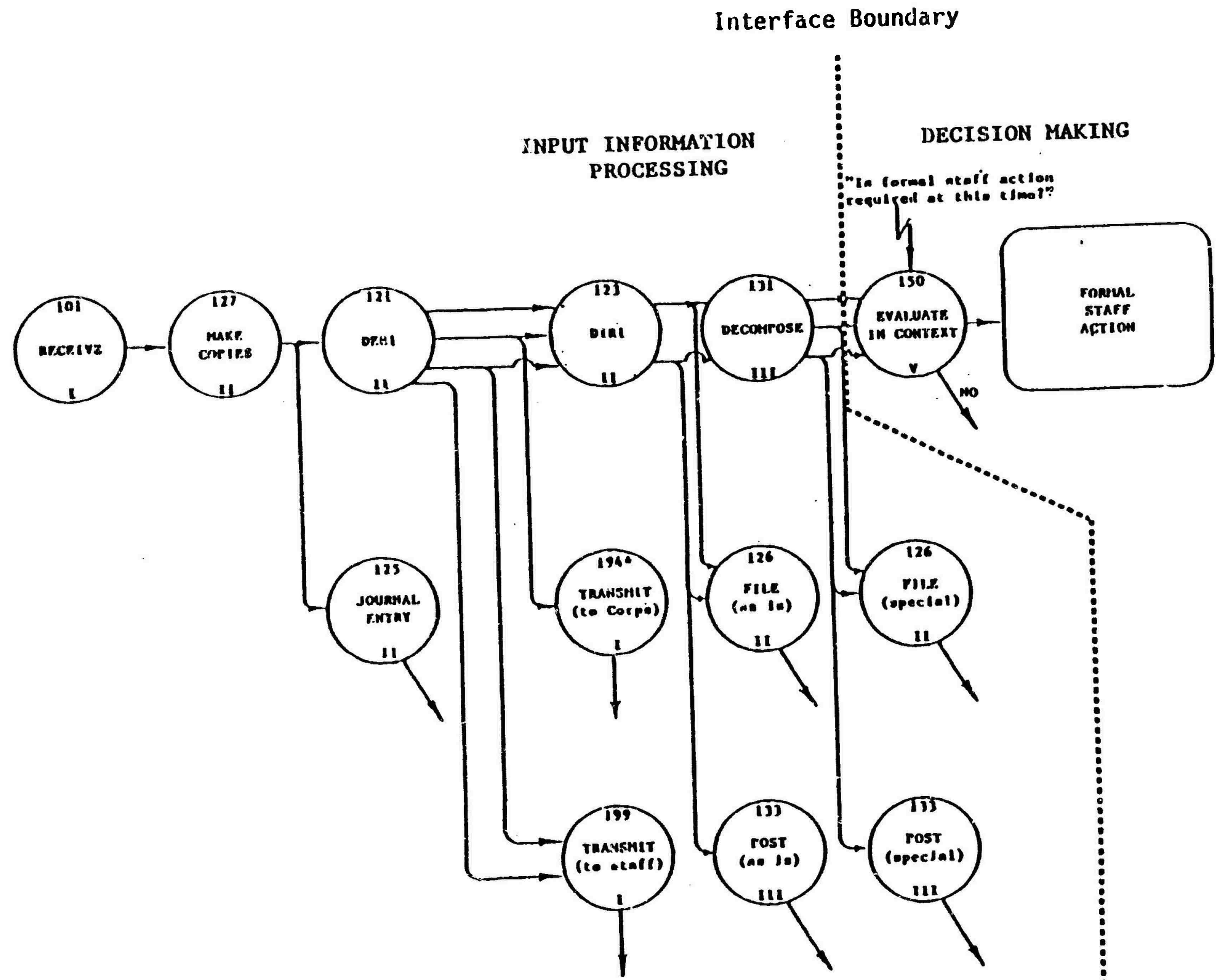

FIGURE 3-11. CATEGORY 1 ACTIONS
Triggered by Receipt of External Tactical Messages from BOG/CORPS

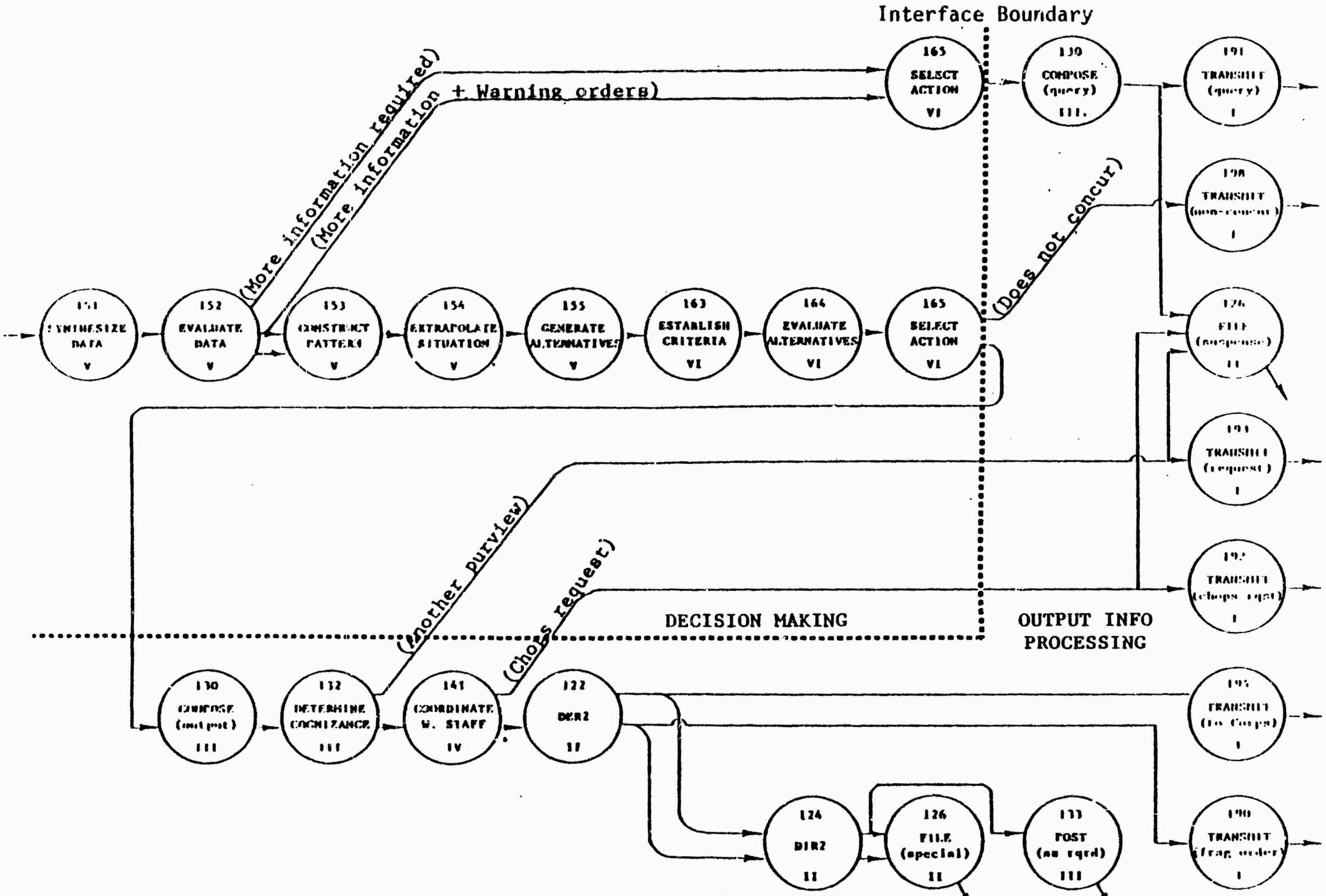

FIGURE 3-12. FORMAL STAFF ACTION SEGMENT

data base as the primary computer storage medium for the body of information regarding the "state of the battle" held by the Blue side. The transfer of data from the perceived data base to the live players was visualized as being limited to about seventy-five standardized tactical message formats whose printing or cathode ray tube display was presented one-at-a-time to the players. The populated modules, in turn, had the responsiblity for maintaining and updating their own section files, status boards, and situation maps so that the tactical decisions they made were based, among other things, on how well they organized, aggregated, and sifted their own data. Now, under the new boundary location described above, it is clear that the computer will take over the input information processing tasks heretofore assigned to the players. But how is this section data base information to be presented to the lone decision-maker when he embarks on the elementary operations EVALUATE IN CONTEXT or SYNTHESIZE DATA? Is he provided with a fully automated situation map display? Can he access any of his section files by means of keyboard queries? With either the extreme boundary position or even an intermediate location closer to the boundaries implied by left and right hand margins of the charts, the computer assistance aspects of the Phase 1 design will have to be enlarged. One part of this expanded requirement, the question of the computer storage of the staff files and displays, is addressed in the next section. The remainder of the questions, such as the added data presentation formats and the software switching, is developed in considerable detail in the companion volume.

3.3 POINTS OF OCCURRENCE OF VARIANT HUMAN PERFORMANCE

This subsection now merges the human performance material developed in Section 2 with the staff processing structures discussed earlier in this section. The objective here is to determine where, in the execution of the staff actions, relevant human errors are likely to occur. The points of occurrence of aberrant performance will provide, with respect to populated staff modules, basic guidelines for the instrumentation of the player team. The determination will also provide, with respect to simulated staff processing, the embryonic logical framework by which the computer/controller(s) may accommodate two different aspects of human error phenomena: first, the simulated processing attendant on substandard performance coming from the live player team, and second, the injection of simulated errors in order to observe the compensating responses, if any, by the live team.

The points of occurrence of human errors in staff processing that are derived here become central to the logical design of the simulated staff modules as presented in Section 4.

3.3.1 Three Classes of Human Error

In Section 2 human errors in staff processing were classified according to their elemental effect on the information processes. Three such classes were identified. This classification is repeated here in order to illuminate the basic relationships with the procedural steps in the staff actions:

- Data Error: Introduction of erroneous or misleading data into the staff section files/displays.
- Procedure Error: Delaying the completion of the staff action by making a false start or an error in performance of an elementary operation.
- Cognition Error: Making the wrong tactical decision because of false or incomplete perception or inadequate selection criteria.

The caveat that went with these effects should also be repeated. It should be clear that while the errors may be observed as discrete occurrences in a live staff module, the consequences of such occurrences, stemming from the cause-and-effect relationships among them, are difficult to predict. A staff section, for example, could issue an incorrect frag order because of at least three different manifestations of human errors. First of all, because of one or more data errors, the decision-maker might construct an erroneous perception of the situation or problem at hand and end up with an inappropriate tactical decision. Second, because of cumulative delays from procedural errors, the decision-maker might come forth with an invalid decision since the decision was based on a situation now three to six hours old. Finally, even though he is confronted with a timely and accurate picture of the situation, the decision-maker himself might fail, as a result of cognition errors, to generate the full spectrum of alternatives or to develop adequate evaluation criteria and therefore end up with the wrong tactical decision. Beyond these three simple sequences there are undoubtedly numerous combinations of the three error classes that could lead to a wide variety of alternative outcomes. Indeed, it can be argued that an ironic "comedy of errors" in command and control is possible under the classifications. A situation could exist where data errors lead to a wholly erroneous picture of the tactical problem. Thereafter the

decision-maker makes a number of cognition errors which fortuitously compensate for the wholly erroneous perception. In this unlikely circumstance the staff section might come forth with the correct tactical response derived entirely for the wrong reasons.

As discussed in paragraph 2.4.4 of the Phase 1 design report[6] not all of these error classes are either observable or measureable directly in the information stream. Data errors and procedural errors can be observed, hence measured, directly because the data stream and/or data base contains a reference standard. Cognition errors, on the other hand, involve the generation of new information not previously contained in the information stream; hence, their effect can be observed only indirectly, i.e., in the outcome of combat. As pointed out above, data errors and procedural errors can also affect combat outcomes. One must, therefore, carefully control the non-cognition errors if the effects of cognition errors are to be isolated.

3.3.2 Frequency of Occurrence

The points of occurrence of the human error effects are identified with respect to the 27 elementary operations in Table 3-5.

The table shows the elementary operations and/or Class 1 events as they are listed in Tables 3-2 and 3-3. The estimated relative frequency of occurrence of the three error effects is shown in the labeled columns. As indicated in Section 2, no adequate data were found in the literature to support the relative frequencies. The estimates shown are based on three broad factors that influence the likelihood of occurrence and that will be used in the computer logic for simulated staff modules. The factors are as follows:

- The nature of the elementary operation itself.
- The redundancy of the information content in the sense of information theory.
- The stress or fatigue experienced by the staff person at the time.

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6 Ibid.

TABLE 3-5

ESTIMATED RELATIVE FREQUENCY OF OCCURRENCE OF ABERRANT PERFORMANCE EFFECTS IN THE ELEMENTARY OPERATIONS

Event No.	E. O. Descriptor	Data Error	Procedure Error	Cognition Error
100	INITIATE BY CLOCK		2	
101-112	RECEIVE OR ACCEPT	3	2	
121	DER1	1	2	
122	DER2	1	2	
123	DIR1	1	2	
124	DIR2	1	2	
125	ENTER	2	2	
126	FILE		2	
127	MAKE COPIES		1	
130	COMPOSE	2	1	
131	DECOMPOSE	1	1	
132	DETERMINE COGNIZANCE	1	1	
133	POST or PLOT	2	2	
134	RETRIEVE		2	
140	COORDINATE W. STAFF	1	2	
141	COORDINATION COMPLETE?	2	1	
150	EVALUATE IN CONTEXT	2	1	
	INITIATE BY SELF	1	1	2
151	SYNTHESIZE DATA	2	1	2
152	EVALUATE DATA	1	1	2
153	CONSTRUCT PATTERN	1	1	2
154	EXTRAPOLATE SITUATION	1	1	2
155	GENERATE ALTERNATIVES	1	1	2
163	ESTABLISH CRITERIA	1	1	2
164	EVALUATE ALTERNATIVES	1	1	2
165	SELECT ACTION	1	1	1
189-199	TRANSMIT or DELIVER	3	2	

Blank - Never occurs
1 - Occurs with relatively low frequency
2 - Occurs with relatively medium frequency
3 - Occurs with relatively high frequency

Thus, it can be seen that data errors are expected to occur with highest frequency in the RECEIVE and TRANSMIT operations and not to occur at all in the FILE and MAKE COPIES operations. Similarly, the procedure errors (slip of the tongue, data entry errors, slips of the pencil, computational errors, etc.; corrected but delaying the execution of the operation) are expected to occur with different frequencies in all procedural steps. Finally, the cognition errors are expected to show up only in the higher level elementary operations.

SECTION 4

LOGICAL DESIGN FOR SIMULATED STAFF PROCESSING

4.0 INTRODUCTION

This section presents the logical design framework for the simulated staff modules in the battle simulation. The section focuses on the added design requirement related to the human errors that are known to occur in the command and control of division-level forces and whose occurrences and effects are an important and promising area for behavioral research applications. The requirement may be stated in terms of two questions about the way the simulated staff modules will operate:

- If the players in live staff modules make errors in the course of executing their staff functions, can the simulated staff modules, subject to the control by investigators/controllers, be made to "adapt" to the substandard human performance so that the consequences of the errors will be reflected in the battle outcome?

- Can the simulated staff modules, again subject to the intervention by the investigators-controllers, be made to exhibit errors in <u>their own</u> staff processing, so that the players in live staff modules may be tested to see if they attempt to correct the mistakes before they are reflected in the battle outcome?

Both questions are oriented to the coordination required between principal staff sections for effective command and control of the division. If the battle simulation can be implemented with the

requisite input control parameters and controller's intervention techniques to provide these features, then the model will open the door to a wide variety of behavioral experiments.

The discussion on simulated staff processing begins by tracing the tactical information flow in the model as a whole, as it was originally conceived in the Phase 1 design. This information flow structure is then refined first by incorporating the details of the staff procedures from Section 3 and second by showing where human errors are involved in the flow cycle. The refined structural framework is then used as the basis for describing the logical design of Class 1 events whose structured sequences make up the simulated staff processing in the model. The design features related to input control parameters and to controller's release events--the mechanisms required for the questions cited above--are then explored. The section is concluded by a review and restatement of the functions required of investigators/controllers in organizing and running behavioral research experiments with the enhanced design concept for the battle simulation.

4.1 TACTICAL INFORMATION FLOW IN THE SIMULATION

One of the principal features of the Phase 1 design concept is the explicit treatment of the flow of tactical information messages between the combat units engaged with the opposing forces and the division Command Group and its chief staff sections. Whenever one or more of the Blue staff modules are manned by teams of human players, the tactical information flow is manifested by the players "receiving" messages from the battlefield and their "transmitting" in turn new frag orders or queries back to the subordinate units. The treatment is explicit because the players are confronted with realistic formats and printed content based on about seventy-five selected tactical message formats.

The flow of tactical information in the model is illustrated in Figure 4-1. The figure shows the flow cycle as it was originally conceived in the Phase 1 design. The flow of information can be seen to circulate through three different conceptual entities: the real world data base, the Blue perceived data base, and the Blue staff modules. A similar flow cycle exists for the Red side, but in keeping with the fundamental asymmetry of the design concept, the Red command and control module consists only of the Red Commander by himself.

The flow of tactical information messages is governed in the simulation by the occurrence of events. The ground-truth facts

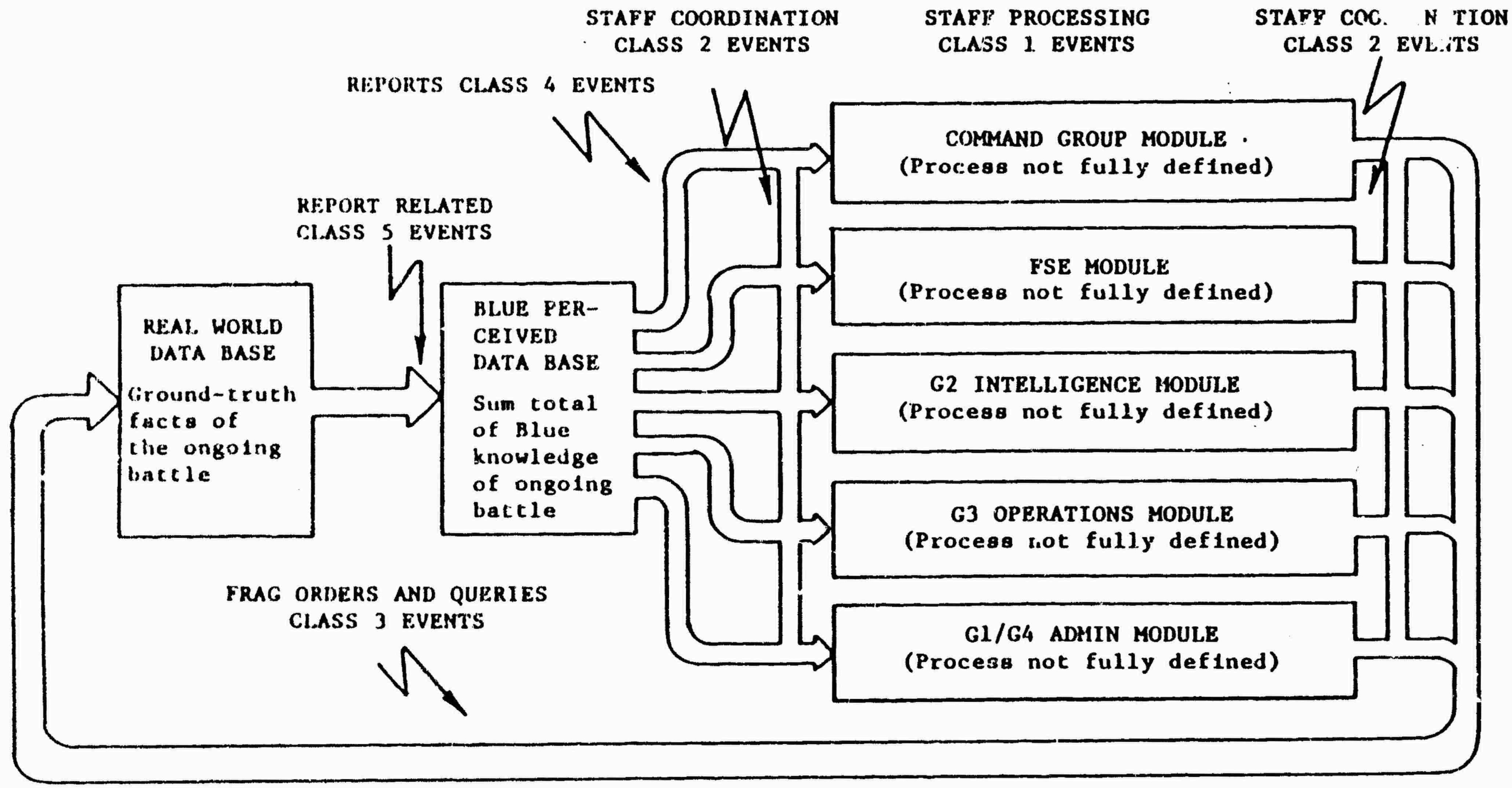

FIGURE 4-1. SIMPLIFIED ILLUSTRATION OF THE TACTICAL INFORMATION FLOW IN THE BATTLE SIMULATION; ORIGINAL PHASE 1 DESIGN

about the on-going battle are carried from the real world data base to the Blue perceived data base by means of report-related Class 5 events. These events cover the intelligence gathering and status reporting activities taking place in the BOG. The general Blue perceptions of the battle are then carried from the perceived data base to the cognizant staff module by means of the Class 4 interface events. The interface boundary between the perceived data base and the staff modules is not shown in the figure, but it is located just to the right of the perceived data base. Upon receipt of the Class 4 reports, the staff modules then establish the flow of input coordination messages by means of the Class 2 events. The description thus far covers the first half of the flow cycle.

The second part of the cycle begins with the staff processing performed by the staff modules. Acting on the basis of the tactical information it receives, each module performs the required command and control functions within its purview and issues or transmits frag orders or queries pertinent to the successful execution of the division's assigned mission. The formulation and generation of these new messages is effected by Class 1 events. The transmission of the messages, carrying the new orders or queries to the appropriate addressees in the BOG, is governed by means of the Class 3 interface events. Concomittant with the staff outputs are the output coordination messages (information copies) shown by the second bar of Class 2 events. The interface boundary between the staff modules and real world data base is also not shown, but it lies somewhere along the bar at the bottom of the figure. This "closes the loop" for the information flow cycle.

Figure 4-1 highlights the fact that the staff processing internal to the staff modules was not fully defined in the Phase 1 design. A preliminary discussion of the concept of Class 1 events was given in Design Note I, but the list of defined events was incomplete for the class because the level of procedural detail to be used had not yet been determined.

The completion of the list of defined Class 1 events and the detailing of the staff procedures from the previous section now permit the first refinement to be made on the picture of the tactical information flow.

4.1.1 Staff Processing Details

The role of staff processing in the information flow cycle can be illustrated by grouping the procedural steps in Action Categories 1, 2, and 3 (Figures 3-2, 3-4, and 3-5; also Figure 3-3) into three basic stages: maintenance and update of the section files/displays, generation of the perception and decision-making, and output processing. Upon receipt of a tactical information message, a staff section usually goes through these three stages of staff processing. For the purposes of showing a refined picture of the general information flow, the subtle variations on this simplified framework implied by the remaining action categories can be ignored for the moment. Action Categories 1, 2, and 3 cover the majority of the staff processing requirements.

The first refinement to the information flow diagram is shown in Figure 4-2. The figure shows that the staff processing in each of the five staff modules consists of the same three basic stages. While the specific types of tactical messages it receives and the specific organization of its files/displays both depend on the area of functional responsiblity for an individual module, the general pattern of information flow through the module is the same for all staff sections.

At this point, a review of the concept behind the perceived data base is pertinent. In the Phase 1 design[1], the Blue and Red perceived data bases were characterized as follows:

"The perceived data base on each side consists of the side's perception of its own troop list and operations SITMAP as well as the enemy order of battle and dispositions. The real world data base and the separate perceived data bases are conceived as distinct bodies of information because neither side will ever enjoy true and full knowledge of the deployment of the units of the other side nor even up-to-date and precise knowledge of its own troops. Accordingly, the basic design concept includes a Blue and Red perceived data base each containing unaggregated information about its own troops and the enemy forces. During the course of the play, the information in these data bases will be continually modified by the occurrences of the Class 5 report generation events. The occurrences will usually be followed by corresponding Class 4 events at which times the staff modules will receive tactical information messages. The messages will be formatted according to standard message formats and based on data aggregated from the perceived data base. Thus, the state of battle

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1 Tiede, R. V., Burt, R. A., and Bean, T. T., Design of an Integrated Division-Level Battle Simulation for Research, Development, and Training (Army Research Institute Draft Technical Report, August 1979).

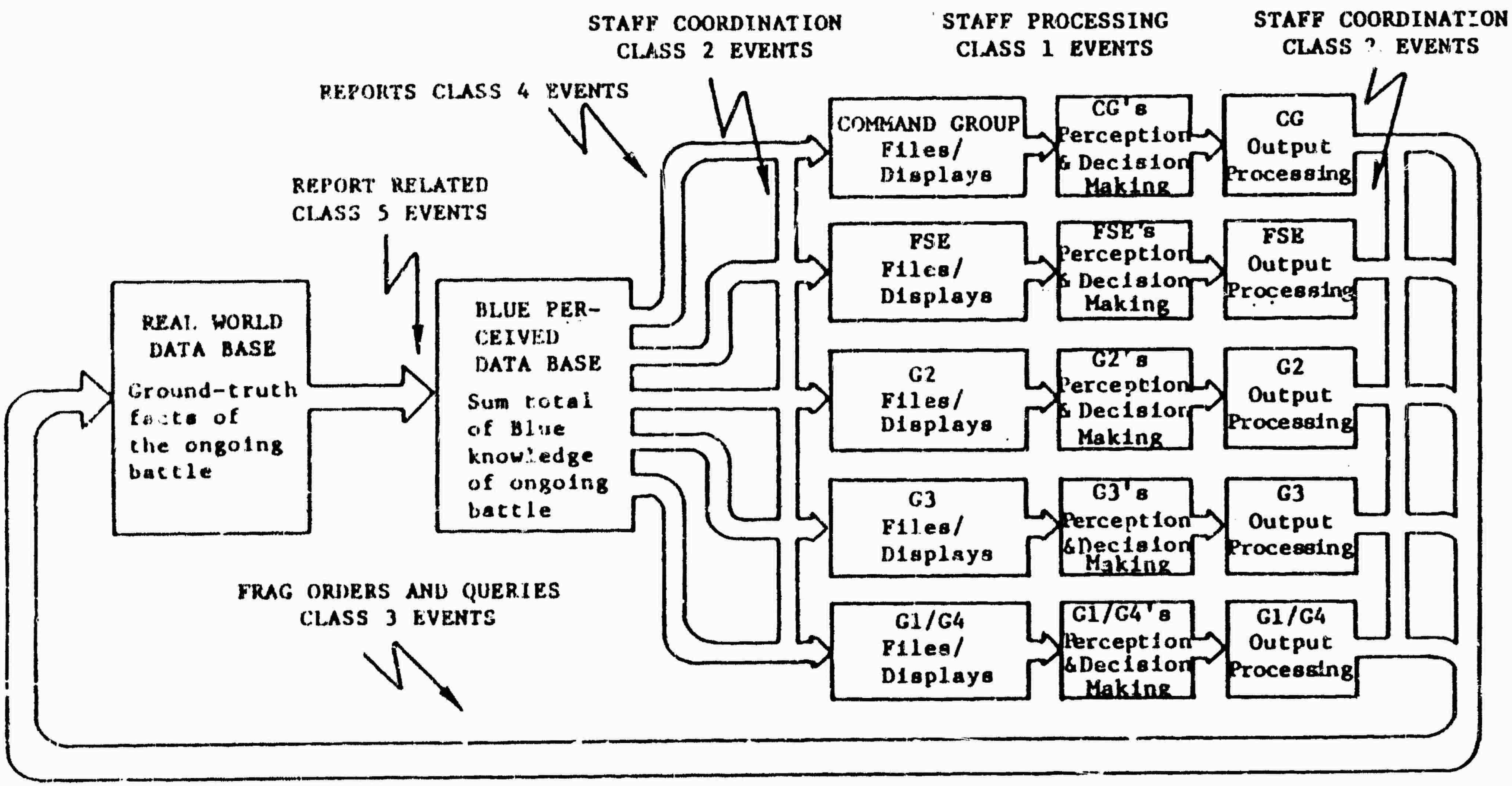

FIGURE 4-2. TACTICAL INFORMATION FLOW IN THE BATTLE SIMULATION, SHOWING THE STAFF PROCESSING

reflected in the information will always be delayed in time and subject to errors and omissions with respect to the true facts in the real world data base."[2]

"In concept, the perceived data base will always exist in two forms: first as tabular arrays of data available ordinarily only to the controller(s) and/or computer, and second as the series of troop lists, modified organizations for combat, situation map overlays, numerous files, etc., set up and maintained by human players in populated staff modules during an exercise. The first form may be thought of as the body of facts about the conflict marshalled by the Blue or Red sides, while the second form will reflect the way the commander and his staff organize, aggregate, and sift the known facts to facilitate decision making."[3]

Now the "first form" of the Blue perceived data base is simply the labeled box shown in Figures 4-1 or 4-2. But the "second form", at least with respect to populated staff modules, is the small box shown as the "section files/displays" for an individual module. The section files/displays box is hereafter called the section data base because it represents the body of information from which the decision-maker generates his perception of a problem and on which he bases his tactical decision. The validity of the section data base, that is, the degree to which the second form corresponds to the first form of the perceived data base, is clearly a function of how well the tactical information from successive messages is incorporated into the section data base.

One could summarize the distinction between the data bases as follows:

- Real World Data Base - information about what really happens in the division-level conflict.
- Perceived Data Base - sum total of knowledge one side holds about the conflict potentially available to decision makers of one side; this

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2 Ibid.

3 Ibid.

information is generated by the intelligence gathering and status reporting functions employed by the side.

- Section Data Base - information taken from the perceived data base but reorganized and sifted according to the area of functional responsibility of the staff section. This is the information actually available to the decision makers.

Figure 4-2 brings out two points worthy of more detailed discussion. The first is related to the difference between manual staff processing and processing with ADP assistance, as seen from the perspective of the general tactical information flow. The second is concerned more concretely with the implementation of simulated staff processing in a computer. The separate issues are discussed below.

4.1.1.1 ADP - Assisted Staff Processing

The general design concept in the Phase 1 report contained provisions for exercising the staff modules not only under a manual staff system but also under a staff system provided with ADP assistance. The design considerations directed toward the latter mode of operation included the following:

- Requirement for an added sixth class of events and for the specification of the alternative tactical information displays associated with these Class 6 events.

- Requirement for additional hardware to provide a realistic environment for the players in a populated staff module.

- Software techniques for asynchronous data entry from several different player's terminals.

- Software additions for emulating the computerized decision-making aids built into the field ADP facilities.

Although these items were fully identified in the basic design, it was recommended that the initial implementation of the model proceed without them because the terminal hardware specifications and the software emulation routines were not fully defined at the time.

The conceptual picture of tactical information flow (Figure 4-2) nevertheless now provides an interesting perspective for comparing a manual staff system with ADP-assisted staff processing. The obvious disadvantage of a manual system as well as its more subtle shortcomings can be revealed by tracing the information flow through the staff processing boxes. The diagram can also be used to identify the fundamental tactical data management objectives for a field ADP system.

The principal difficulty with a manual staff system lies in the first stage of action processing shown in the figure. Maintenance and update of the section data base attendant on the receipt of a tactical message are performed entirely by hand by subordinate members of the staff section. Management and processing of the vital tactical data are handled by means of complicated staff procedures consisting of a large number of elementary, and sometimes trivial, operations. Since the categories of staff actions in Section 3 are oriented to a manual staff system, the complexity and time-consuming aspect of the input information-processing can be seen by looking at the front end of the event thread charts (e.g., Figures 3-2, 3-4, and 3-5).

The amount of time taken for information-processing before the senior staff officer can begin to formulate his perception of the situation can often spell the difference between effective or inadequate command and control, even if the successive tactical messages were to come in at reasonably spaced time intervals. The time delays are predictably much worse, however, whenever the staff element experiences a "busy hour" when the tactical messages are coming in simultaneously on several different communications channels, one after another. An earlier study[4] has shown that the time necessary to complete the input processing or the entire staff action

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4 Tiede, R. V., Walker, M. E., Stenstrom. D. J., and Sweeny, S. O., The Integrated Battlefield Control System (IBCS) Third Refinement Study (McLean, Va.: Science Applications, Inc., Final Report, March 1975)

can be lengthened as much as 100% or more simply because the E4 or E7 performing the initial input operations has an inordinate number of tasks piled up in his in-basket.

A second, more obscure problem with manual systems can be demonstrated by referring again to Figure 4-2. The basic idea behind the perceived data base and the individual section data bases is that each section data base represents a recasting of the "state of the battle" information from the perceived data base according to the section's area of functional responsibility. This means that the five staff sections are, in principle, looking at the same picture of the conflict but are extracting nuances (i.e., tactical data) from the picture that are relevant to their separate areas of responsibility. This is fine just so long as the coordination between the staff sections is sufficient to assure that they continue to look at the same overall picture. Staff coordination in fact serves two basic purposes. First it is a mechanism for detecting and correcting gross errors. Secondly it serves to keep the separate section data bases reasonably well coordinated.

In a manual system, the staff coordination procedures are executed entirely by staff personnel. A breakdown or failure of staff coordination due improper procedures or to human errors will inevitably lead to section data bases that are no longer based uniformly on the same picture of the war. In short, in a manual system, when the five cooks attempt to taste the soup from the same pot on the stove, human errors will serve to sprinkle more salt or sugar into the soup spoon as it passed among them.

These shortcomings within a manual staff system immediately suggest the direction and thrust that one would expect to be taken in the development of ADP facilities to assist in the concentration of forces by a division commander. An ADP system should be overlaid on division structure to provide basic automated processing capability down to the desired echelon. Furthermore, the system should be designed to provide the capability to exchange data both internal and external to the division, to build and maintain data files, to perform analysis support, and to provide a graphic display capability to support division operations.

Implicit in these requirements is the recognition that each of the subordinate units on the battlefield "sees" different aspects of the perceived data base indicated in Figure 4-2. There is a natural tendency for knowledge among and between staffs (derived from

the perceived data base) to diverge if there is not a conscious effort to institute and execute staff coordination procedures. Even with excellent vertical and lateral staff coordination the knowledge on the part of each unit will tend to diverge due to time delays, human errors and the orientation of each unit. Accordingly, it has been seen as a significant problem area on today's dynamic battlefield and ADP systems should provide the battlefield with a common data base, accessible by all units. This concept would provide all commanders with the required level and detail of information which would lead to more timely analysis of the dynamic battlefield and reduce the uncertainty in decision making.

There is also a requirement for section data base within each unit's staff. This feature must provide each staff section the capability to extract information that it needs in order to execute its function on a continual basis. As each staff inputs new information or modifies existing information the common data base is essentially updated for all other users. This concept reduces information processing times, decreases the possibility of compounding human error and increases the effectiveness of staff coordination at all levels.

It is clear then that a battlefield ADP system, if implemented properly, can alleviate most of the problems associated with the vertical and lateral transfers of information among all division units. However, it is conjectured that the ADP system should not only alleviate information processing problems but it should also provide an additional bridge between the information and the ultimate decision made by staffs. That is, decision-aiding techniques could, among others be applied to enemy activity and movement, enemy order of battle, logistical considerations, and the most likely outcome of alternative courses of action.

The Phase 1 design addressed and resolved many of the issues brought out above. For example, the simulation has been designed as a storage and retrieval system for incoming and outgoing messages as they pertain to the division staff. All of the various staff modules, whether populated or simulated had access to a common "perceived" data base. The design of this perceived data base was modeled upon the automatic receipt and distribution of incoming messages based on specific message characteristics. To design the common perceived data base, reporting requirements of the division were ascertained and the data utilization at the division-level was assimilated into the information flow of specific staff modules.

This design concept had the advantage of allowing populated staff modules to structure their own section data base from incoming tactical messages and queries made to the common perceived data base. Players, however, would not directly interact with the computer. This design met the Phase 1 design objectives in that it closely approximated the existing manual system and would therefore allow experimental psychologists to examine human behavior within the desired environment. The introduction of the Phase 2 requirements for modeling variant human behavior and for reducing the populated modular boundaries has forced the examination of the design from a TOS-like perspective. Specification of automatic routing of transmitted as well as received messages within simulated staff modules, as defined in the staff action categories of Section 3, will now permit the reduction of the boundaries around a populated module and thus increase the economy of operations[5]. Under such a mode, the players will now be directly involved with the computer.

This idea has grown out of the Phase 2 requirements and has provided significant insight on how to achieve the objectives of an ADP assisted command and control system. It leads to the following conclusions:

- That a common data base does not, without special processing, provide information in a structure that is of immediate utility to a variety of users such as that represented by a division staff.
- That the information contained in the common data base should be manipulated by the computer and displayed to the functional user in a manner that is of immediate utility to him.

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5 Although this boundary reduction is technically feasible, the credibility and realism of the simulation may suffer. This trade-off is addressed further in the companion report.

The "files/display" boxes of Figure 4-2 are a representation of this design philosophy and as such the design will facilitate the simulation of an ADP assisted command and control system. The design and design alternatives presented throughout the remainder of this report will adhere to this section data base concept.

4.1.1.2 Computer Implementation of Simulated Staff Processing

A large part of the Phase 1 report was directed at the cost-benefit trade-offs that were implied if computer assistance were used to implement different elements of the basic design. The discussion began by considering the size and organization of the total body of data on which the exercise of the battle simulation would be based. It was then shown, on the basis of these data structure requirements, that an effective tool for research, development, and training could be developed using the computer (1) to set up the exercise and (2) to assist in the timing and the pursuit of the research objectives while the exercise was running. The first of these functions was embodied in a three-stage preprocessing system which lead to a SCENARIO File. The second function was handled by an interactive executive control routine (IECR) which read the SCENARIO File and then embarked on the dynamic portrayal of the combat situation. The two software packages, as well as the file that bridged between them, were based on the common data structure conceived for the overall system.

The five major data groups contained in the required data structure were as follows:

- Real World Data Base
- Blue Perceived Data Base
- Red Perceived Data Base
- Event Table
- Message Format Specifications and Data Element Dictionary

These data groups were estimated to take up 316,000 bytes of data space in the computer. The data space requirements, along with the instruction space requirements, provided the basis for formulating the cost-benefit judgements.

It should now be clear that the Phase 1 data structure omitted the data space requirements for the section data bases. Prior to this Phase 2 study, it was tacitly assumed not only that the simulated staff modules would operate like idealized division staff elements but also that they would, where required, make reference, not to their own section pool of information, but to the unaggregated tactical information in the perceived data base. In the original concept, section data bases were defined as the section files/displays used by live staff modules and located entirely outside the computer.

The discussion now turns to the question of computer-stored section data bases. Should the basic data structures of the simulation software be expanded to include a sixth major data group covering section data bases? The software design already contains two data bases: the Real World Data Base and the Perceived Data Base. It will now be shown that the incorporation of a third data base (consisting of five separate section data bases) will provide a more realistic portrayal of the tactical information flow as well as the simulated staff processing, but will require significantly increased software development as well as expanded preprocessing functions devolving on the investigators/controllers. The division-level battle simulation can be built without the third data base, but the simulated information flow and the simulated staff activity in this framework will exhibit subtle discrepancies in the tactical information messages and tactical data displays presented to the live players. Because this development/realism trade-off is ARI's prerogative, the logical design material presented in the next subsection will be found to be approached from two separate points of view: first using the expanded data structure containing the third data base and then using the more limited framework without computer-stored section data bases.

The principal reason the third data base will improve the simulated staff processing and the information flow in the model is that it will represent the "state of the battle" information held at any moment by the division staff. If the model is exercised assuming a manual staff system, the body of information held by the staff will consist of five separate section data bases, each containing tactical data organized and filed according to the particular functional requirements of the staff section. If the model is exercised assuming

an ADP-assisted command and control system, the same body of information will represent the common tactical data base associated with the field computer system. The common tactical data base may be partitioned with respect to the separate staff section functions and will always be accessed and/or updated by the separate sections according to the rules and data organization specified for the field ADP system. When emulating either a manual mode or an ADP-assisted mode, however, the third data base will be subject to changes in its state of the battle information only through discrete occurrences of Class 1 events (staff processing operations) or Class 2 events (staff coordination exchanges). Any individual item of tactical data in the data base will remain at its unmodified value or setting until it is updated or changed by a specific action performed by either man or machine in the division staff system. For example, if the G3 section files the latest SITREP received from the first brigade, the entire tactical data contents of the report will remain unchanged in the data base until superseded by the receipt and filing of the next SITREP from the same brigade.

In contrast to this, the perceived data base will be changing dynamically throughout the simulated combat. With each occurrence of the Class 5 events related to the on-going intelligence gathering and status reporting activity in the BOG, individual data items in this data base will change continually in a manner almost entirely indpendent of the actions taken by the personnel or machines at division headquarters. In the example above, the tactical data contents of the Brigade SITREP sent to the G3 will correspond to the situation data in the perceived data base only for the moment in time at which the Class 4 event occurs. Ten minutes later, or five hours later, the same situation data items will have changed in the perceived data base while the material in the SITREP on file with the division staff will remain unchanged.

This property of the third data base is important in the realistic simulation of staff processing because several elementary staff operations (e.g., RETRIEVE and SYNTHESIZE DATA) involve the accessing of tactical data already on file in the data base. The added data base can emulate either the section files/displays used by a manual staff system or the common tactical data base contained in a field computer system. The "state of the battle" information held in this body of data will be subject only to the manipulations stemming from staff operations.

There are other, lesser advantages to incorporating the third data base. Under a manual mode of staff operations, one of the

basic problems was shown to be the inevitable divergence that developed between different section files/displays during the course of combat operations. These tactical data discrepancies arise because of human errors that occur in the coordination processes between staff sections. By using suitable software data organization, the third data base can provide a means to measure this divergence as it develops in an exercise of the model.

The third data base can also be used in a special manner wherever one or more of the staff modules are populated as staff sections under a manual system. The actual section data bases of these teams will consist of the filing cabinets, display boards, and situation maps the players will use and maintain during the exercise. The software section data bases, which would ordinarily not be involved in the play, could in fact be maintained in parallel by the computer and provide thereby a comparison standard for the real section files/displays outside the machine. With a live G3 module, for example, the Front Line Trace could be compared at the end of the run against a printout from the third data base.

Under an ADP-assisted staff system, the third data base will facilitate the generation and formatting of the alternative tactical data displays used by live staff modules. It will also facilitate the use, by either populated modules or simulated modules, of alternative sets of access and update rules that might be specified for the automated command and control system. These implications of the added data structure are developed further in Section 5.

The cost of third data base, in terms of the added software development and the extended preprocessing functions, can be summarized as follows:

- The added data space requirement for the sixth major data group is estimated to be 100,000 bytes. This makes the overall requirement 416,000 bytes.

- The software data organization of the new data base will have to be hardwired in the computer programs. For manual mode applications, the section data base subdivisions will have to be tailored to the separate

areas of responsibility of the different sections. For ADP-assisted mode applications, the rules for accessing/updating the common tactical data base will have to be based on the software design of the field computer system.

- The preprocessing functions in preparation for an exercise of the battle simulation will have to include the added task of initializing the third data base. This task is visualized as being incorporated in the Phase II Preprocessing Program. The initialization would ordinarily be made consistent with the Blue Special Situation and the research objectives set forth for the exercise.

4.1.2 Human Errors in the Staff Processing

A second refinement is now made to the picture of the tactical information flow in the battle simulation. This refinement delineates those segments of the flow cycle where the separate classifications of human errors become involved.

The second modification to the information flow diagram is shown in Figure 4-3. The figure now shows that data errors and procedure errors can occur at any point between the receipt of a tactical information message by the staff module and the end of the staff processing when the module transmits its decision to the appropriate addressees on the battlefield. The figure also shows that cognition errors can occur only during the second stage of the processing where the decision-maker himself performs the higher level operations on the tactical information. The segments of human error involvement are based on the points-of-occurrence material from paragraph 3.3.

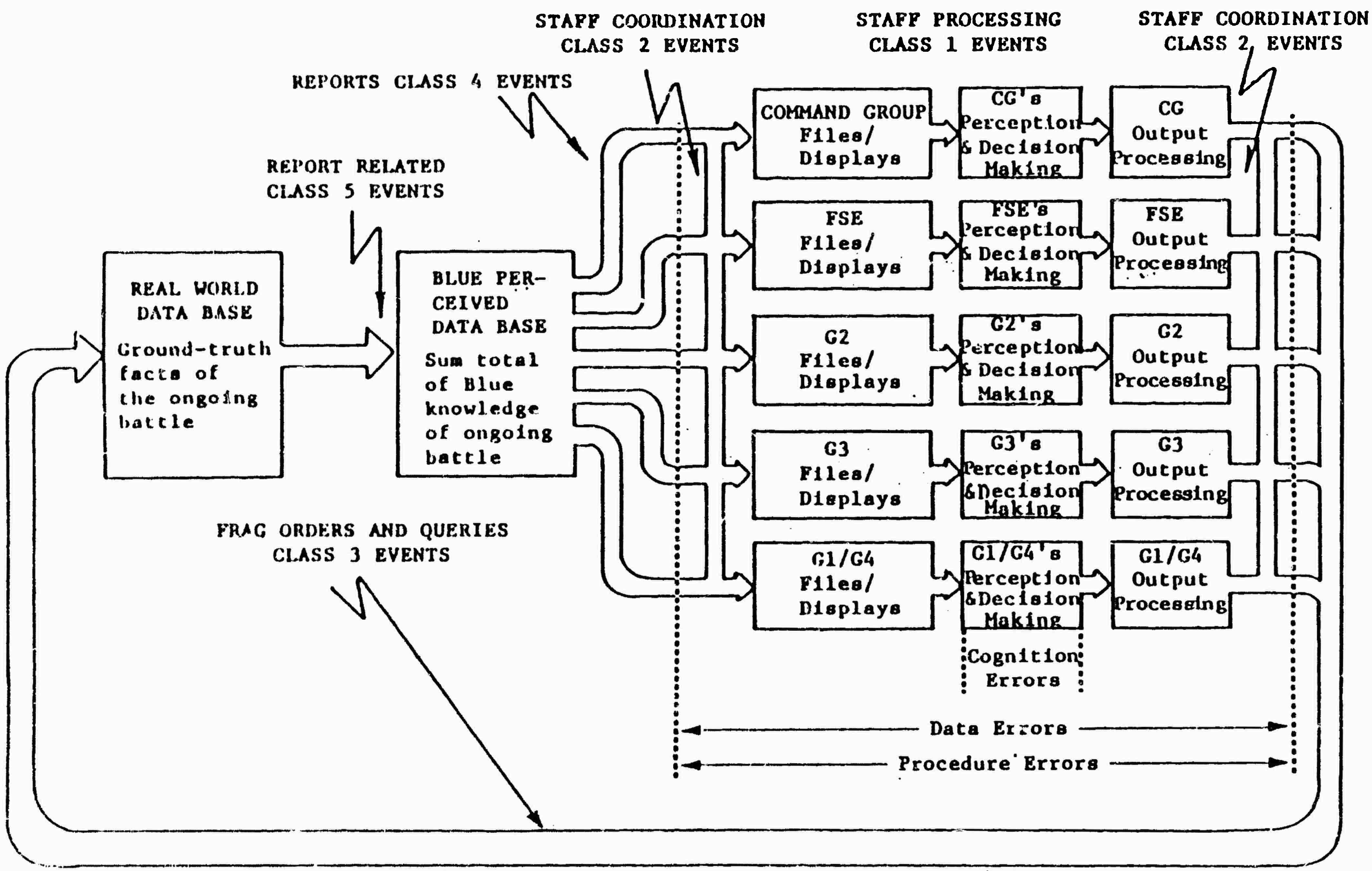

FIGURE 4-3. TACTICAL INFORMATION FLOW SHOWING HUMAN ERROR REGIMES

The areas of error involvement given in the figure should be interpreted as the areas where error effects can occur with some non-zero probability. The arrows should not be taken to mean that the probability is uniform from one end to the other. It will be shown later in this section that the simulated occurrences of human errors to be incorporated in the simulated staff modules will be based insofar as possible on calculated probabilities which change from one processing step to the next in accordance with the three factors given in paragraph 3.3.2. The indicated regimes denote some non-zero probability of occurrence; the actual probabilities will vary from step to step in the simulated staff processing.

It should also be noted that Figure 4-3 exhibits for the first time the interface boundaries of the staff modules. The boundaries are the dotted lines coincident with the beginning and the ending of data and procedure error effects. They represent the base-line boundary locations delineating the entire staff processing event sequence shown in each of the staff procedure categories in Section 3. The ability to relocate the boundary positions so that the live staff modules encompass only a selected portion of the staff procedures is the subject of the next section. Under the base-line locations shown, the live staff procedures now include all the low-level, repetitive operations which may serve to detract from the desired thrust of some behavioral research experiments.

4.2 CLASS 1 EVENT LOGIC

The discussion thus far has taken the two areas: (1) human errors in command and control and (2) the detailed structure of division staff processes, and merged them, in order to focus on the behavioral research experiments that might be run using the Integrated Division-Level Battle Simulation. The preliminary material in this section, furthermore, has served to sharpen the focus by showing where and how substandard human performance perturbs the tactical information flow cycle in a combat situation. This subsection now shows how, in the framework of the complicated structure, the computer can be made to simulate the staff processing in such a manner that the investigators/controllers may control the incidence of substandard staff performance in simulated modules. With a research tool of this kind, where the investigator can manipulate the simulated staff performance that is part of the environment the live players will face, a wide range of behavioral experiments can be run.

The key element in this kind of model is the logical structure of the Class 1 events. Class 1 events were identified in

the original Phase 1 design as the staff processing occurrences within the individual simulated staff modules. The list of such events has now been completed and the structured sequences making up the different categories of staff actions have been specified in Section 3 of this report. The level of detail with which the simulated staff processing will be treated has also been fixed; Class 1 events represent elementary staff operations performed by one person. The discussion now shows how the computer logic for these events should be approached in order to provide the flexibility of control required above.

4.2.1 Principles of the Approach

The proposed general approach to Class 1 event logic is to develop algorithms oriented to the individual information-processing or decision-making operations performed by human beings. The algorithms will make reference to, and operate on, selected items of tactical data from the input message, the section data base, and/or the Blue perceived data base, in accordance with definitions of the elementary operations. The algorithms will also inject human data and procedure errors (but not cognition errors) on a chance basis, governed by sets of computed probabilities that will depend on the nature of the individual operations, the nature of the data, and the workload environment at the time. The probability calculations will contain a control factor that is set by the investigator/controller prior to the exercise. The control factor will allow the user to preset the incidence of occurrence of data and procedure errors, but not to pinpoint the operations or times at which they occur.

This kind of logic in the Class 1 events will serve adequately in simulating the low level staff processing operations and even certain sequences of decision-making operations where the human decision-maker's perception of the problem and his decision alternatives are more-or-less routine. The logic is clearly inadequate and incomplete, however, for simulating the higher level decision-making operations when the decision-maker is faced with a complex command and control problem. The computer, even if it used new artificial intelligence techniques, cannot be programmed to model such processes of the human brain as generation of a perception of the

situation, hypothesizing the missing elements in a pattern or picture, synthesizing the weighting factors associated with a set of alternatives, or selecting the best course of action. The autonomous algorithms described above, at least for some of the higher level staff processing operations, must provide some kind of mechanism for letting the investigator/controller intervene and direct the cerebrations of the simulated staff officer.

The general approach to Class 1 event logic, therefore, will be based on separate, self-contained routines for each defined event, but with the added feature in certain sequences for triggering the interactive participation of the investigator/controller to guide the decision-making operations. Thus the approach will divide the Class 1 events into two subclasses as follows:

- Class 1A Events - those events in which the simulated operation is explicitly represented and includes the chance occurrence of data errors and procedural errors.

- Class 1B Events - those events which will function like Class 1A events unless the tactical importance of the staff action calls for controller intervention. If controller intervention is signalled, then the simulated operation will be effected by interactive input from the controller.

These subclass distinctions provide the basis for the more detailed discussion presented in subsequent paragraphs. The approach, however, involves two basic operational features in the model that bear on its essential cost-effectiveness as a research tool for behavioral experiments. The first is the Monte Carlo technique to be employed in the random occurrence of human errors. The second is the trade-off that exists in using controller intervention as the means to simulate staff processing in the simulated staff modules. These features are discussed before the logical structures of Class 1A and 1B events.

4.2.1.1 Monte Carlo Technique for Human Error Occurrence

The Phase 1 design placed considerable emphasis on the capability of the model to provide "the basis for repeated exercises

of the same experiment, carried out under identical conditions but using different human players." The battle simulation had to present the same division-level combat situation to successive teams of players whether the exercise was oriented to a behavioral research experiment, to a combat developments application, or to a training problem for division staff personnel. This "repeatability" requirement was largely satisfied through the proposed use of the SCENARIO File which was a permanent information storage medium such as a magnetic tape or computer disk and on which was recorded not only the fully initialized real world data base and Blue and Red perceived data bases but also the input control parameters consistent with the specific objectives of the exercise.

The introduction, here in the Phase 2 study, of the idea of Monte Carlo techniques to control the incidence of human errors in the simulated staff processing presents a problem in maintaining the repeatability of experiments. If a random number generator is used to "roll the dice" with respect to the occurrence of human errors, how can the model be made to present the identical occurrences in the same simulated staff actions in successive exercises? Most Monte Carlo simulations are structured so that successive runs of the computer program provide different results, and the overall result must be derived from the statistical ensemble of many separate runs. On the other hand, here in the battle simulation it is required that the pattern of random human errors in the simulated modules be repeated in successive exercises.

According to the general approach described above, each Class 1A algorithm will contain a random number test for possible occurrence of a data or procedural error. The test may be expressed as:

$$R_n \quad P_e$$

where R_n is a random number between 0 and 1, and
P_e is the computed probability.

If the test is successful, the algorithm will invoke the appropriate error effect. A data error will inject a selected item of erroneous or misleading tactical data. A procedural error will lengthen the simulated time interval for the completion of the elementary operation.

If the test fails, the algorithm will simply reflect no occurrence of the human error.

The requirement for repeatability of experiments means that the "throw of the dice" given by the random number R_n must be the same in successive exercises so that if the simulated module encounters the same staff processing sequence for the same input tactical message it will reflect the same pattern of errors. Of course, the computed probability P_e can in principle be influenced indirectly by the live players and thereby modify the pattern of errors. For example, a live staff module could stimulate the "paper mill" processing actions of the simulated module and increase its workload. Since the workload experienced by the simulated section is one of the factors governing the calculated probability, the random number tests would reflect a different pattern. But insofar as the random number phasing is concerned, the battle simulation should continue to provide for the repeatability of exercises based on the same SCENARIO File.

4.2.1.2 Controller Intervention

The Phase 1 design introduced the idea of controller intervention by stating that "there will always be certain Class 1 events and Class 5 events in which the controller(s) must intervene in order to supplement the logical rules of the simulation or to influence the onslaught of events on a populated staff module. These Class 1 or Class 5 events are therefore further qualified as release events, because the controller(s) must execute their release, that is, complete the intervention <u>on or before the time of occurrence</u> as measured on the simulated clock."

"Controller intervention by means of release events is one of the key features of the model. Although some types of release events are simply a convenient means for handling certain kinds of staff inputs to populated modules, the basic reasoning behind most release events is as follows:

- Release events provide a means for the investigator/controller to influence the play in order to direct the exercise toward the research objectives.

- Release events provide a means for a human being to provide certain processes such as terrain analysis, identification of routes of advance, etc. which would otherwise call for much larger computer data requirements.

- Release events provide a means for the controller(s) to invoke military judgement in certain parts of the simulated battle.

The implementation of release events will begin by identifying all those occurrences among the Class 1 and Class 5 events where controller intervention is required. Provision must then be made that the progenitors of these events trigger the pending action warning to the terminal oprator. Each identified release event must then be provided with its own formatted screen and edit/update routine through which the terminal operator will enter the requisite data for release."[6]

Thus the Phase 1 design anticipated the requirement for controller intervention in the higher level decision-making operations in the simulated staff modules. The Class 1 events in which the controller must intervene are the Class 1B events discussed below.

The central problem with release events, however, lies in the overall burden of control functions that must be carried by the controller(s) during the running of exercises. In order for the basic design to be directed toward a cost-effective research tool, the Phase 1 report stressed the idea of minimizing the control functions so that exercises could always be managed and directed by no more than two qualified personnel. Release events represent a particularly stressful part of the controller's responsibilities because the interactive release of the events is subject to the timing requirements established by the event-oriented computer routine. Under a real-time exercise, for example, the controller would be required to effect the release of the engagement cycle event (no. 508) every 15 minutes for each separate combat engagement on the battlefield. Each such release might require input data reflecting the routes of advance or withdrawal of the opposing forces tailored by the controller's military judgement of the situation.

Now, under this general approach to simulated staff processing, the controller(s) will also have to effect the release of Class 1B events whenever the computer determines that the tactical importance of the action is critical to the simulated outcome. Although the trigger thresholds for determining the decision-making release events will be adjustable through input data, the

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6 Op cit, Division-Level Battle Simulation, pg. 4-61.

controller(s), during an exercise, will necessarily rely on the pending action warning associated with release events, because, unlike the cyclic pattern of engagement events described above, the timing of the Class 1B events will not be easily anticipated.

4.2.2 Class 1A Events

Class 1A events are staff processing events that simulate the execution of individual elementary operations. Their logical structures will represent explicitly the information processing and decision making operations performed either by human beings (as in a manual staff system) or by field computer (as in an ADP-assisted system). The separate algorithms will operate on the tactical data associated with the input message, the section data base, and/or the Blue perceived data base, and will simulate the amount of time necessary to complete the operational step. The algorithms will also employ the random number tests for the chance occurrence of data errors or procedure errors as described in paragraph 4.2.1.1.

There will be a separate algorithm for each Class 1 event listed in Table 3-2.

Those algorithms associated with Level V and VI operations will contain additional logical structure which will determine whether the staff action involves a sufficiently significant departure from normal routine to warrant controller intervention. Such events, of course, are Class 1B events. The controller's intervention to substitute for the decision-maker's cognitive processes is discussed further below. But if the logic determines that the Level V or VI operations are more-or-less routine in nature, then the remainder of the algorithm is just like that of a Class 1A event.

The distinction between Class 1A events and Class 1B events is illustrated in Figure 4-4. This figure is a macro logical flow diagram of the algorithm for Event 150 - EVALUATE IN CONTEXT. The elementary operation is a Level V in which the decision-maker determines whether formal staff action is required at the time (i.e., event time) when he first becomes aware of the input message. The elementary operation can be seen to be part of Staff Action Categories 1, 2, and 3 (Figures 3-2, 3-4, and 3-5). In these event threads there are two possible outcomes from the execution of the operation: either formal staff action is initiated or else the action started by the receipt of the input message is terminated.

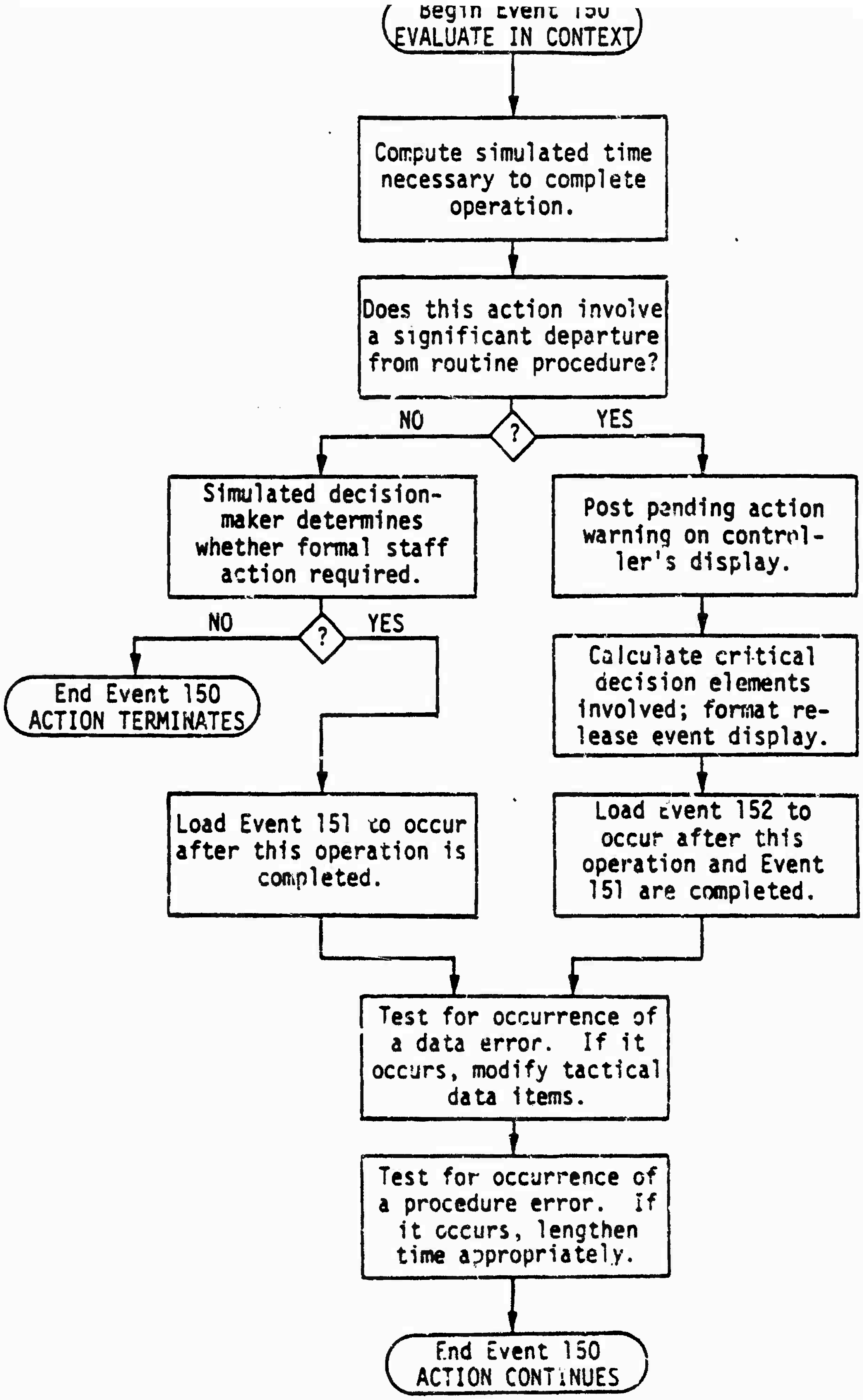

FIGURE 4-4. LOGICAL FLOW DIAGRAM OF EVALUATE IN CONTEXT

EVALUATE IN CONTEXT is a Class 1B event because there are, in all three categories, input tactical messages spelling out significant departures from routine staff activity. Examples are as follows:

- In Category 1: G2 receives an NBC Report.
- In Category 2: G3 receives a retransmitted copy of a Combat Intelligence Report.
- In Category 3: G1/G4 receives a non-concurring chops response from G3.

In each of these staff actions the cognitive processes required of the simulated decision-maker must be provided through controller intervention.

In the diagram, the logical flow on the right-hand branch is the added structure provided in a Class 1B event. The left-hand branch, and the remainder of the boxes are the required structure for all Class 1A events.

One important logical property should be noted in the algorithm for EVALUATE IN CONTEXT. If the computer decides that the tactical importance of the action calls for controllers intervention, the determination of whether formal staff action is required becomes automatic. The simulated decision-maker will always "decide" on immediate formal staff action whenever the action is more than routine staff processing.

4.2.2.1 Using Computerized Section Data Bases

The discussion above makes clear that all Class 1 events will be implemented by computer routines containing the required, Class 1A logical structures. Only a small number of the routines will possess additional Class 1B logical structures providing the automatic switch for controller intervention to substitute for the decision-maker's cognitive processes. The question now arises; how will the Class 1A logical structures operate if the simulation software provides for section data bases? As stated in the last subsection, section data bases are the bodies of information in the separate staff sections from which the decision-makers generate their

perceptions of problems and ultimately base their tactical decisions. Each staff section organizes its section data base according to its own area of functional responsibility. In a manual staff system, a section data base consists of the filing cabinets, tote board displays, situation maps, etc., all organized (and used) according to particular area of responsibility of the staff section. Now suppose the simulation software provided computer files that were organized and filled with tactical data in a manner emulating a real staff section under a manual mode. How, in this framework, would the simulated staff modules work?

The simulated staff processing using the third data base will be based on Class 1A logical structures which will explicitly modify, update, and retrieve tactical data in the section data bases according to the definitions of the elementary operations. This means that those operations associated with putting data into the section data bases will explicitly add more tactical data items or else update existing items; and those operations associated with data extraction will explicitly read the data from its appropriate computer file. The operations related to the former are hereafter called <u>update operations.</u> They are as follows:

- Event No. 125 ENTER
- Event No. 126 FILE
- Event No. 133 POST or PLOT

These are the only operations in which data are put into the section files/displays*. The second and third items in the list involve a wide variety of different data repositories across the five staff sections. The operations involved with data extraction are hereafter called <u>retrieval operations.</u> They are as follows:

- Event No. 134 RETRIEVE
- Event No. 141 COORDINATION COMPLETE?
- Event No. 150 EVALUATE IN CONTEXT
- Event No. 151 SYNTHESIZE DATA

These are the only operations in which data are read out of the appropriate repositories*. The remainder of the operations may involve manipulation of tactical data from input messages, or data items already extracted from the section data base, or simply procedural rules to be followed in staff processing; they do not involve the explicit update or retrieval of data from the third data base.

* The reader is reminded that this section treats simulated staff modules only. In populated modules the cognitive elementary operations may involve additional access to files.

4.2.2.2 Without the Section Data Bases

If the software design does not provide computer files for the third data base, the Class 1A logical structures for the update and retrieval operations will have to be set up in a different manner. The update operations will not involve the explicit placement of data items in an appropriate data repository; instead the algorithm will simply mark time to simulate the time necessary to complete the operation. The tactical data items contained in input tactical messages will already be resident in the perceived data base at the times the messages are received by the staff. The tactical data items constituting the staff output frag orders will be lost in the sense that after the frag orders have been transmitted to the addressee(s) in the BOG, there will be no repository of data representing the file copies of issued orders.

The retrieval operations will have to access tactical data from the perceived data base. Without a third data base, the only body of information that can represent the section files/displays is the body of unaggregated tactical data in the second data base. Although the algorithms can be structured so that they aggregate (or reaggregate) the tactical information according to the retrieval format requirements, the information in the perceived data base may very likely have changed at the time of retrieval. As stated in paragraph 4.1.1.2, the perceived data base will change dynamically throughout the simulated conflict in a manner more-or-less independent of any actions taken by the personnel (or machines) in the division staff. Simulated staff processing under this stilted framework can be illustrated by the following vignette:

> At 1000 hours, the G3 receives a SITREP from the first brigade. After noting that there are no significant changes in the first brigade situation, he files the report so that it may be used when the Division SITREP is to be prepared. The update operation FILE is simulated by marking off a completion time of one minute without any explicit transfer and storage of tactical data. At 1130 he embarks on the preparation of the Division SITREP. In synthesizing the data for the report, he withdraws from file the brigade SITREP received at 1000 hours. The retrieval operation SYNTHESIZE DATA is simulated by accessing the perceived data base and reformatting the first brigade SITREP from the tactical data. However, the precise contents of

this reconstructed report may not be the same as that received at 1000 hours. During the intervening 90 minutes of simulated combat, the data of the perceived data base could reflect a considerable difference in the situation for the first brigade. While one might conclude that the reconstructed report represents an improved basis for preparing the Division SITREP, the updated situation report actually represents a distortion of reality in the simulated staff processing.

4.2.3 Class 1B Events

The Class 1B logical structures will provide the mechanism which allows the investigator/controller to intervene and substitute for the decision-making operations in a simulated staff module. The mechanism will consist of three parts, as follows:

- Discrimination logic to determine whether the staff action involves sufficient departure from routine to warrant controller intervention.
- A means to display a pending action warning for the controller. This warning must be posted some five or ten minutes before the release event is scheduled to occur.
- A routine providing interactive data entry procedures by which the controller effects the release of the decision made by the simulated decision-maker.

The first two parts of the mechanism as well as certain preparatory aspects of the third are illustrated as macro logic boxes in Figure 4-4.

Class 1B logical structures will encompass a slightly different thread of Class 1 events in each of the seven staff action categories. Category 5 Actions (Figure 3-7) will never involve controller intervention at all. In each of the remaining categories these will be three events delineating the sequence of decision-making

operations that the controller will direct. The first event is the "trigger" event which contains the discrimination logic and which posts the pending action warning for the controller if intervention is required. The second event is the release event itself whose release must be effected by the controller on or before the time of the event. The third event is the last decision-making operation in the sequence before the simulated processing reverts back to wholly Class 1A logic structures. Table 4-1 identifies the three events for each of the relevant staff action categories.

The general requirements for the controller's release routine will involve special edit/update software and special formatted display screens. A trade-off will exist between the human engineering requirements for simple keyboard procedures and the limited display screen size and core space in the computer. The information displayed to the controller when he must release a decision will have the following special requirements:

- It must show the staff action category and type of tactical message that has triggered the decision-making.
- It must show the critical decision elements which the decision-maker is addressing.
- The critical decision elements must reflect all the data errors that might exist in the decision-maker's perception.
- It must show the alternative procedural choices open to the decision-maker. For example, in the formal staff processing of a tactical message from the BOG, there are three alternative procedural choices in the decision-maker's operation EVALUATE DATA.
- It must provide for the insertion of a cognition error.
- It must provide for the keyboard entry of the selected action.

TABLE 4-1.

CLASS 1B LOGICAL STRUCTURES IN THE STAFF ACTION CATEGORIES.

Staff Action Category	"Trigger" Event	Release Event	End of Sequence
1	Event No. 150 EVALUATE IN CONTEXT	Event No. 152 EVALUATE DATA	Event No. 165 SELECT ACTION
2	Event No. 150 EVALUATE IN CONTEXT	Event No. 152 EVALUATE DATA	Event No. 165 SELECT ACTION
3	Event No. 150 EVALUATE IN CONTEXT	Event No. 152 EVALUATE DATA	Event No. 165 SELECT ACTION
4	INITIATE BY SELF	Event No. 152 EVALUATE DATA	Event No. 165 SELECT ACTION
5		(none)	
6	Event No. 100 INITIATE BY CLOCK	Event No. 152 EVALUATE DATA	Event No. 154 EXTRAPOLATE SITUATION or Event No. 165 SELECT ACTION
7	Event No. 151 SYNTHESIZE DATA	Event No. 154 EXTRAPOLATE SITUATION	Event No. 154 EXTRAPOLATE SITUATION or Event No. 165 SELECT ACTION

The limited screen size and the short period of time the controller will have to execute the release of the decision will preclude the display and provision for the enumeration of action alternatives and the evaluation criteria to be used in the action selection. The controller will have to assimilate these aspects of the process from his knowledge of the on-going simulated conflict.

4.2.3.1 Cognition Errors

Unlike data errors and procedure errors, both of which will be simulated by means of a Monte Carlo process, cognition errors will be simulated by explicit keyboard insertion during the release of a decision. The frequency of occurrence of such errors as well as the substantive meaning in terms of the wrong decisions drawn by the decision-makers will be handled entirely as part of the controller's intervention.

As a consequence of this logical structure, simulated staff processing will accommodate the occurrence of a cognition error only if the action involves critical tactical questions alling for a release event. Simulated cognition errors will never occur in more-or-less routine staff actions involving Class 1A logical structures by themselves.

4.2.3.2 Internally Initiated Actions

Category 4 Actions, as described in paragraph 3.2.1.4, are actions that are spontaneously initiated by a senior staff officer because he holds a perception of the situation or problem in his mind and is spurred to act on it at once. In simulated staff modules Category 4 Actions will be triggered by the elementary operation INITIATE BY SELF. INITIATE BY SELF will require special treatment beyond that described above for Class 1B logical structures. In order

to simulate internally initiated actions, the controller will be required to insert the event but without any prior timing guidance from the simulator. The computer software cannot be made to anticipate the moment "when the light comes on" in the mind of the simulated decision-maker. Consequently, the triggering by the controller will require data entry of both the timing of event (when does the decision-maker initate the action?) and the subject matter (what is the problem he is addressing?). It is assumed that such entries will always be made in the dynamic framework of the event progression observable by the controller and with the basic objectives of the exercise firmly in mind.

4.3 CONCLUSIONS ON SIMULATED STAFF PROCESSING

On the basis of the considerations brought out in Section 2, Section 3, and the preceding discussion of this section, it is concluded that the first added design requirement of the Phase 2 study, namely, to structure the simulated staff modules in the model so that they can accommodate variant human staff performance is achievable with certain qualifications. Software can be developed that will simulate the staff processing in the event thread framework specified by the staff action charts in Section 3. These routines can be tied to certain input parameters that will provide (1) investigator control of the simulated human staff performance and (2) investigator control of the simulated staff response times. The first set of parameters will allow behavioral scientists to establish the human performance environment for the live players in populated modules; the second set will allow the model to be exercised either under a manual staff system or else in a staff system using ADP assistance.

The salient operational characteristics of simulated staff modules are presented below, first for a manual staff system and second for a staff system provided with ADP assistance. The qualifications attendant on these conclusions follow thereafter.

4.3.1 Simulated Staff Processing in a Manual System

The simulated staff modules can be made to operate with the following properties for a manual staff system:

- Realistic time delays for each elementary operation. The median time delays may be preset by input parameters.

- Random occurrences of data errors and procedure errors, governed by other input parameters.

- Normal coordination and review responses if the populated modules make errors in their staff actions.

- Investigator/controller intervention (with release events) whenever the simulated decision-maker must address important tactical decisions.

4.3.2 Simulated Staff Processing in an ADP-Assisted System

The simulated modules can be made to exhibit the following properties for an ADP-assisted staff, based on the same software structures:

- Realistic time delays for each elementary operation but with rapid responses for machine operations and slower responses for those operations still performed by human beings.

- Random occurrences of data errors and procedure errors but only for those operations performed by personnel.

- Input, output, coordination, and review processes will be largely automated, but the simulated modules will exhibit normal responses if the live modules make errors in their staff actions.

- Controller intervention as described above.

4.3.3 Qualifications

The following qualifications are associated with this approach to simulated staff processing:

- Insufficient data have been found to exist for the relative frequencies of occurrence of the three types of human errors.

- Insufficient data have been found for human performance times on elementary operations involving ADP terminal devices.

- The discrimination logic necessary to determine whether controller intervention is substituted for the simulated decision-maker has not been fully designed.

- The critical decision elements associated with a controller-inserted decision have not been fully identified.

The lack of applicable error analyses may well be a blessing in disguise in that it forces the simulation design to accommodate a wide range of error frequencies. This means the behavioral researcher will be provided with considerable flexibility for studying human error effects. The model may become a vehicle for accumulating a body of needed data on human performance in staff information processing. The discrimination logic and the associated decision elements will require additional work. They will be addressed in more detail at a future date.

SECTION 5

PRINCIPLES OF TASK DESIGN

5.0 INTRODUCTION

This section develops guidelines for the design and implementation of player tasks in an interactive simulation. The approach to this development assumes that an existing or conceptual tactical information system has been defined and is being emulated on an available simulation of (division/corps level) battle. It is further assumed that a detailed standard operating procedure (SOP) for the populated staff module in the system being emulated has been specified. The purpose of the development in this section is to define the changes and/or additions to such a specified SOP that may be required to insure that the required variables are controlled or are measurable. Trade-offs among task realism, credibility, and impact on performance measurement are discussed. Viewed in this context, task design is inextricably interwoven with the design of the populated modules and with experimental design. The discussion, therefore, begins with the purpose of the staff system, the nature of staff decision making and some of the implications therefrom. It then examines some of the trade-offs developed in the companion volume for staff module design but which equally affect task design. Other factors affecting task design, to include simulation design and purpose of the experiment are also examined as a basis for developing principles of task design. A set of procedures for formulating task design is provided.

5.1 PURPOSE OF STAFF SYSTEM

5.1.1 Staff Functions.

The Staff Officer's Field Manual[1] states:

- "Command is the authority that a commander in the Military Service exercises over his subordinates by virtue of his rank or assignment. Command includes the authority and responsibility for effectively using available resources and for planning, organizing, directing, coordinating, and controlling military forces for the accomplishment of assigned missions. The commander alone is responsible for all that his unit does or fails to do . . . He is assisted in performing command functions by deputy or assistant commanders and a staff . . ."

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[1] U.S. Department of the Army, Staff Organization and Procedure, FM 101-5, Washington, July 1972.

- "The staff consists of officers who are specifically ordered or detailed to assist the commander. . . Five functions are common to all staff officers:

  - Providing information
  - Making estimates
  - Making recommendations
  - Preparing plans and orders
  - Supervising the execution of plans and orders."

Clearly, these five functions are cyclic in that supervising the execution of plans and orders provides new information which can be the basis for continuing the cycle. It should also be noted that this set of functions falls into the pattern of Class 1 (Staff Processing) events depicted in Figure 4-3, i.e.,

Supervising the execution of plans and orders and providing information	Produces	Section Files/ Displays
Making estimates and recommendations	Results	Perception and Decision Making
Preparing plans and orders	Amounts to	Output Processing

In summary then, it may be said that the purpose of the military staff at any echelon is to facilitate <u>human</u> decision making.

5.1.2 <u>Nature of Military Decision Making</u>.

Paragraph 3.1 defined the elementary operations involved in staff information processing and identified the higher level or cognitive processes which are the essence of decision making. Paragraph 3.2 developed the sequence in which these operations are normally performed in processing staff message traffic. Paragraph 4.1 aggregated these operations and showed that they clustered into the operations required to maintain and update section files and displays, the cognitive processes associated with decision making, and the processes required for output processing. This is illustrated in Figure 4-3. Now, the cognition processes (Level V and VI elementary operations) can operate only on data already stored in the decision maker's short term/operating memory. If additional data are needed for any of the processes, the cognition processes stop until the needed data are

retrieved from long-term memory or the environment for which files and displays are surrogates. From this it follows that the principal purpose of the staff section data base (particularly the visible files and displays) is to extend human operating memory for the cognition processes. In fact, if such aids to memory are not provided, the decision makers will improvise them.

It should also be noted that most formal Army instruction in staff operations and procedures (primarily at the Command and General Staff College) has, in the past, largely concentrated on the decision making processes. Because of the high quality of the information provided to him (even though it may be incomplete and contain uncertainties), the student is hardly aware of the decision maker's dependence on the lower level information processing functions. He gains the impression that all of the pertinent information generated at subordinate, adjacent, and higher echelons is somehow made available to decision makers. Not until he has had field experience is he aware of the amount of hard, grubby labor involved in creating and maintaining a useful data base. On the other hand, the discussions in Section 4 clearly show that the opportunity for error and delay in information processing before and after decision making is far greater than in the actual decision making and the impact of such delays and errors on combat outcome is more fundamental.

It follows that studies and research in the area of military decision making cannot be limited to studies of the decision making functions but must include information processes to include their errors and delays as well. Further, to be useful, automation must concentrate on supporting the decision making functions by providing pertinent, coherent, readily available data for decision making and assistance in the cognitive processes as well.

5.1.3 Implications.

A number of implications pertinent to task assignment can be drawn directly from the preceding discussion:

- The transfer of information between an information system or a simulation thereof and a live decision maker always involves lower level (I - IV) information processes.

- No matter where you place the man/simulation boundary some level I - IV processing must still be performed by the decision maker in order to transfer data from the system to his short-term memory and vice-versa.

- To the extent that the decision maker participates in the lower level processes, he has already transferred significant data from the data stream into memory and thus circumvented the formal transfer of data from a message or file when it arrives before him for action. By the same toke, to the extent he is precluded from participating in the normal level I - IV processing, he must add such processing to transfer data into his short-term and long-term memory. Such preclusion could result from task assignment in the manual mode or from system design in the ADP-assisted mode.

- Effective decision aiding systems will effect this transfer more efficiently and effectively than does participation in the formal manual mode processing.

- In the manual mode, decision maker participation in lower level processes permits him to create shunts from these lower level processes to the cognition processes without waiting for the completion of the lower processes. This permits the cognition processes to be initiated sooner and to be carried out in parallel with the lower level processes. Without such parallel processing the manual staff would be overwhelmed by even a modest workload.

- Such shunting to the cognition processes tends to reduce reliance on files and displays and to substitute reliance on memory.

5.2 RESULTS OF TRADE-OFF ANALYSES

In Section 5 of the companion volume to this report[2] there is a series of analyses of the trade-offs involved in moving the boundaries of a populated staff module toward the decision maker in order to reduce the cost of operating such a module. As has already been indicated, many of the considerations in task assignment to personnel in the populated module are quite similar to those involved in changing module boundaries, i.e., in moving the interface between the simulation and the players. For example, the effect on the decision maker(s) in the module is much the same if the module boundary excludes all or a portion of the lower level staff processes

[2] Tiede, R. V., Burt, R. A. and Bean, T. T., On the Design of Simulations of Command and Control Processes, Science Applications, Inc., McLean, VA, 15 September 1980.

or if the task assignment prescribed for the decision maker precludes his participation in those processes. It is, therefore, worthwhile to summarize these considerations in a series of tables (Tables 5-1 through 5-7) because of the insights they provide as to the limitations of these different configurations and to facilitate later analysis of the control and measurability of variables that each provides. These tables evaluate each of seven different configurations of which the first five are variant emulations of a manual staff module and the last two are emulations of an ADP-assisted staff module. Each series of tables (5-1 and 5-6) begins with a configuration in which all of the elementary operations performed by personnel in the mode being emulated (manual and ADP-assisted, respectively) are performed by players. The succeeding variants eliminate more and more elementary operations from the module until only the cognitive functions are being performed by players; all the rest are performed within the simulation. (See the companion volume for more detailed definitions of the various configurations.) The task assignment analog to this would be a series of task assignments for the decision maker which successively prevented him from participating in an increasing portion of the lower level processes.

In Tables 5-1 through 5-7, the different configurations are evaluated with respect to the following attributes:

- REALISM. Each variant is rated in terms of the degree of realism with which it is possible to replicate the operating environment of the staff module being emulated. For example, in Table 5-1 the configuration is one in which all elementary operations performed by personnel in a staff module processing information in a manual mode are performed by players and it is rated "Excellent" for realism. In contrast, Table 5-5 evaluates a configuration in which players perform only the cognitive operations of the same manual staff module. It is rated "Poor" as to realism.

- MEASUREMENT. Each variant is rated with respect to its inherent capability to measure several of the performance parameters associated with behavioral experiments. These include:

    - PROCESS TIMES, i.e., the length of time required to carry out each elementary operation which presupposes that it is also possible to

[2] Ibid.

TABLE 5-1. EVALUATION OF CONFIGURATION A

CONFIGURATION: A

SYSTEM EMULATED: Manual

PLAYER PERFORMED EOs: All

REALISM: Excellent

MEASUREMENT OF:

- PROCESS TIMES:

  Lower Level Processes--Good. All measurable.

  Cognitive Processes--Poor. Shunting prevents timing initiation; transition between processes not identifiable in manual mode.

- ERROR RATES:

  Lower Level Processes--Poor. Under high stress conditions which are of great interest for error phenomena, there will be reluctance to reduce voice traffic to hard copy--hence, no standard for error detection.

  Cognitive Processes--Poor. With voice communication maximum shunting occurs, hence, large reliance on memory and no record of data actually used in decision making.

- ACCESSION FREQUENCY:

  Poor. High shunting rate and associated reliance on memory prevent measurement of decision maker access to incoming or stored data.

INPUT VARIABLE CONTROL: Poor. Two factors militate against. Voice input communication requires large number of controllers which inevitably dilutes control. Voice communication (overhearing traffic) makes control of information flow within staff module impossible.

COST:

- PERSONNEL: Exhorbitant
- HARDWARE/SOFTWARE: Low

TABLE 5-2. EVALUATION OF CONFIGURATION B

CONFIGURATION:	B
SYSTEM EMULATED:	Manual
PLAYER PERFORMED EOs:	All except RECEIVE and TRANSMIT by voice

REALISM: Good, but not as good as Configuration A

MEASUREMENT OF:

- PROCESS TIMES:

  Lower Level Processes--Good, except for RECEIVE and TRANSMIT by voice.

  Cognitive Processes--Poor. Shunting still occurs and transition between operations not identifiable in manual mode.

- ERROR RATES:

  Lower Level Processes--Good. Hard copy provides standard for error detection.

  Cognitive Processes--Poor. To the extent shunting still occurs because of decision maker participation in lower level processes, it is not possible to determine what data were the basis for decisions.

- ACCESSION FREQUENCY:

  Poor (+). Better than Configuration A, but to the extent decision makers still participate in lower level processes, shunting makes it impossible to measure actual data accessions.

INPUT VARIABLE CONTROL: Medium. Significantly better than Configuration A, but some uncontrolled information flow (shunting) still occurs.

COST:

- PERSONNEL: Medium. Significant reduction in control personnel.
- HARDWARE/SOFTWARE: Medium

TABLE 5-3. EVALUATION OF CONFIGURATION C

CONFIGURATION: C

SYSTEM EMULATED: Manual

PLAYER PERFORMED EOs: All except RECEIVE and TRANSMIT (VOICE) and INVISIBLE FILES

REALISM: Medium. Decision maker can still participate in some lower level processes (Visible Files), but his accession to data in invisible files must be far more structured.

MEASUREMENT OF:

- PROCESS TIMES:

  Lower Level Processes--Medium. Many have been eliminated.

  Cognitive Processes--Poor. Some shunting to visible files still occurs and transition between operations not identifiable.

- ERROR RATES:

  Lower Level Processes--Medium. Many have been eliminated.

  Cognitive Processes--Medium. All shunting except to visible files has been eliminated.

- ACCESSION FREQUENCY:

  Medium. Data accession to visible files is now measurable.

INPUT VARIABLE CONTROL: Good (-). Only visible file shunting remains uncontrolled.

COST:

- PERSONNEL: Medium. Non-visible files can be automated.

- HARDWARE/SOFTWARE: Medium. Non-visible files are automated.

TABLE 5-4. EVALUATION OF CONFIGURATION D

CONFIGURATION: D

SYSTEM EMULATED: Manual

PLAYER PERFORMED EOs: All except RECEIVE and TRANSMIT (VOICE), NON-VISIBLE FILES, and DISPLAYS

REALISM: Poor. So little of staff complement is present.

MEASUREMENT OF:

- PROCESS TIMES:

  Lower Level Processes--Poor. Very few performed.

  Congitive Processes--Poor. Transitions between operations not identifiable.

- ERROR RATES:

  Lower Level Processes--Poor Very few performed.

  Cognitive Processes--Good. All shunting is eliminated; data used for decision making are identifiable.

- ACCESSION FREQUENCY:

  Good.

INPUT VARIABLE CONTROL: Good.

COST:

- PERSONNEL: Medium.
- HARDWARE/SOFTWARE: High.

TABLE 5-5. EVALUATION OF CONFIGURATION E

CONFIGURATION: E

SYSTEM EMULATED: Manual

PLAYER PERFORMED EOs: Cognitive only

REALISM: Poor.

MEASUREMENT OF:

- PROCESS TIMES:

  Lower Level Processes--Poor. None performed.

  Cognitive Processes--Poor. Transitions between operations not identifiable.

- ERROR RATES:

  Lower Level Processes--Poor. None performed.

  Cognitive Processes--Good.

- ACCESSION FREQUENCY:

  Good.

INPUT VARIABLE CONTROL: Good.

COST:

- PERSONNEL: Low.
- HARDWARE/SOFTWARE: High.

TABLE 5-6. EVALUATION OF CONFIGURATION F

CONFIGURATION: F

SYSTEM EMULATED: ADP-Assisted

PLAYER PERFORMED EOs: All not automated in field

REALISM: Excellent

MEASUREMENT OF:

- PROCESS TIMES:

  Lower Level Processes--Good.

  Cognitive Processes--Good. Transitions between operations are measurable at terminal.

- ERROR RATES:

  Lower Level Processes--Good.

  Cognitive Processes--Good.

- ACCESSION FREQUENCY:

  Good.

INPUT VARIABLE CONTROL: Good.

COST:

- PERSONNEL: Low.
- HARDWARE/SOFTWARE: High.

TABLE 5-7. EVALUATION OF CONFIGURATION E^1

CONFIGURATION: E^1

SYSTEM EMULATED: ADP-Assisted

PLAYER PERFORMED EOs: Cognitive only

REALISM: Poor. But substantially better than Configuration E.

MEASUREMENT OF:

- PROCESS TIMES:

  Lower Level Processes--Poor. None performed.

  Cognitive Processes--Good.

- ERROR RATES:

  Lower Level Processes--Poor. None performed.

  Cognitive Processes--Good.

INPUT VARIABLE CONTROL: Good.

COST:

- PERSONNEL: Low.
- HARDWARE/SOFTWARE: High.

measure the amount of time each action spends in queue awaiting the next elementary operation. This evaluation is further divided between the ability to measure process times for lower level processes and cognitive processes. To continue the example used above, Configuration A (Table 5-1) is rated "Good" for lower level processes, but Configuration E (Table 5-5) is rated "Poor" because none are being performed. On the other hand both configurations are rated "Poor" for measuring cognitive processes because the transition between cognitive processes is not detectible in the manual mode.

- ERROR RATES, in particular, for data errors and procedure errors. (As has already been reiterated in para 3.3, cognition errors are not detectible within the information system.) This quality is also evaluated separately for lower level processes and cognition processes. The capability to measure errors is directly dependent on the presence of hard copy in the data stream. If no hard copy of an action is produced, error detection becomes extremely difficult. By the same token when hard copy is not the basis for cognitive processes it becomes difficult, if not impossible, to distinguish between data and cognition errors.

- ACCESSION FREQUENCY. This quality refers to the capability to determine the data elements retrieved by the decision maker from the data base in order to perform the cognitive processes. To the extent data elements are shunted into the decision maker's memory as a result of performing or exposure to lower level processes, accession frequency becomes impossible to measure.

• INPUT VARIABLE CONTROL. This attribute refers to the experimenter's capability to control such variables as: the amount and kind of information provided, time constraints imposed on decision making, and the quality of the information provided (in terms of errors, omissions, and delays between event and report). It also includes the objectivity with which player decisions are entered in the battle outcome generator and the

strict adherence of controllers to experimental objectives. Two factors can militate against such control. One is the factorial explosion of controllers required for voice communication with the staff module. The other is the absence of control over the data flow within a fully populated staff module operating in the manual mode. These two factors combine to make it virtually impossible to run very many kinds of experiments with a fully manned module in the manual mode using voice communication. The degree of control clearly increases the more lower level processes are precluded.

- COST. This factor is evaluated in terms of the numbers of player personnel required and the estimated hardware/software costs. Tables 5-1 through 5-7 indicate that the number of personnel is reduced as lower level processes are removed from module. This, of course, assumes that ADP is replacing human processing whether this takes place inside or outside the module (ADP assistance to the control element). If, in the manual mode, lower level processes are simply shifted from the players to the controllers, there is no corresponding reduction in personnel. By the same token, to the extent that ADP replaces lower level processing (whether in the module or in the simulation), hardware/software costs increase.

5.2.1 Summary.

Table 5-8 summarizes the results of the foregoing trade-off analysis. A number of implications of this analysis are immediately apparent:

- The cognition processes can be adequately measured and controlled only in the ADP-assisted mode (Configurations F and E^1).

- Configuration B is best for studying the lower level processes except, of course, receive and transmit.

- Configuration F is best for studying ADP-assisted systems because there are no advantages, but several disadvantages, in going to Configuration E^1.

TABLE 5-8. SUMMARY OF TRADE-OFF ANALYSES

CONFIGURATION	SYSTEM BEING EMULATED	REALISM OF STAFF PROCESSING	EFFECTIVENESS FOR BEHAVIORAL EXPERIMENTS: MEASUREMENT OF: PROCESS TIMES		ERROR RATES		ACCESSION FREQUENCY	INPUT VARIABLE CONTROL	PERSONNEL REQUIRED	HARDWARE/ SOFTWARE COST
			LOW LEV	COGNITIVE	LOW LEV	COGNITIVE				
A	Manual	Good	Good	Poor	Poor	Poor	Poor	Poor	High	Low
B	Manual	Good(-)	Good	Poor	Good	Poor	Poor(+)	Fair	Med	Med
C	Manual	Fair	Fair	Poor	Fair	Fair	Fair	Good(-)	Med	Med
D	Manual	Poor	Poor	Poor	Poor	Good	Good	Good	Med	High
E	Manual	Poor	Poor	Poor	Poor	Good	Good	Good	Low	High
F	ADP-assisted	Good	Good	Good	Good	Good	Good	Good	Low	High
E[1]	ADP-assisted	Poor(+)	Poor	Good	Poor	Good	Good	Good	Low	High

5.2.2 Examples.

Before dismissing configurations other than B and F as purely arbitrary constructs with little practical application it is useful to look at some examples of other configurations that have, in fact, been applied for various applications in the past. This sets the stage for the notion that there may be more subtle reasons for using some of the other configurations for specific applications. That notion is developed in para 5.4 below.

5.2.2.1 Configuration A.

This configuration is the one most often used for training staffs and staff sections in actual military organizations. It was also the configuration used to measure the performance of division staff sections in a series of workshops conducted at Ft Hood, Texas, in 1974[3]. Since a principal purpose of that series of tests was the determination of the actual information flow in a fully manned staff section operating in the manual mode, this configuration appeared to be the only reasonable choice. It was during that series of tests that the authors first observed the shunting phenomenon and its effect on information routing and processing.

5.2.2.2 Configuration E.

It is pertinent to cite two examples of the employment of this configuration for completely diverse purposes:

- Classroom Application. Already mentioned in para 5.1.2 is the classroom application at military schools such as the Command and General Staff School. The purpose of this application is to provide instruction in techniques useful for the cognitive processes involved in situation recognition and action selection. Except for very limited student participation in the file, post/plot, coordinate, external routing, and compose processes, all lower level pre-processing is carried out well in advance by the faculty and thoroughly reviewed to eliminate errors and ambiguities that might interfere with the instruction. Clearly this procedure is not readily adaptable to on-line operation. In fact, one of the shortcomings of this mode of operation is that for a continuing scenario the data base must

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3 Tiede, R. V., Walker, M. E., Stenstrom, D. J. and Sweeny, S. D., The Integrated Battlefield Control System (IBCS) Third Refinement Final Report, Science Applications, Inc., McLean, VA, 31 March 1975.

be continually purged to eliminate the student's contribution to earlier phases (unless it just happened to coincide with the "school solution"). Hence, the student never finds out what would have been the result of implementing his own solution.

- SIMTOS[4]. For this application Configuration E was chosen in order to study the decision making process itself. As in the case of the classroom application, a data base was created in advance and it was accessible by the decision maker either on demand or automatically. There was, of course, no dynamic interaction between decision maker outputs and a continuing scenario.

5.3 IMPACT OF COMMUNICATION MEDIA

Since the various configurations described above drastically change the mix of communication media employed to transmit data both to and from the decision maker, it is worthwhile to examine the controllability and measurability constraints imposed by each. In this discussion it is assumed that the data reduction problem inherent in audio/visual recording precludes use of this technique for data collection in any practical sense. It also assumes that burdening the subject/players with any significant degree of data collection would defeat the purpose of the experiment. It should also be noted that the constraints attributed to each of the communication media treated below apply if that communication medium alone is being utilized. The constraints resulting from combinations of media are treated in para 5.4 below. The discussion in the following subparagraphs treats the following characteristics of the media:

- Is access to the data base by the decision maker controlled and measurable?
- Is the duration of the decision maker's access measurable?
- Are errors in the data flow measurable?
- Is shunting inherently associated with the medium?

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[4] Levit, Heaton, and Alden, Development and Application of Decision Aids for Tactical Control of Battlefield Operations, Honeywell Systems and Research Center, Minneapolis, MN, December 1977.

5.3.1 Voice Communication.

To the extent that data base information is transmitted within the staff module by means of voice communication, the decision maker can neither be denied access to it nor can his access be readily measured in terms of duration of access or errors in transmission. This is at the very heart of the shunting phenomenon which short-circuits the formal information flow path and tends to make the data base an entity which is shared in the memories of all members of the staff team, but especially the decision makers. It is this phenomenon that makes the all-manual staff module (Configuration A) so difficult to analyze. However, any effort to control the "Chatter" which is such an integral part of manual processing and to substitute written messages for all intra-module communication seriously distorts normal staff behavior. Configuration B is probably the best compromise for studying the lower level processes because it does impose significant constraints on the information input to the module without affecting unduly the lower level processes other than "receive" and "transmit."

5.3.2 Written Messages.

To the extent that written messages can be substituted for all intra-module communication, all of the difficulties of control and measurement associated with voice communication are overcome. Clearly, this communication mode automatically constrains access to the data base. The exchange of written messages provides an easily observable physical act which facilitiates measurement of process times. The written message also provides "ground truth" which facilitates detection of data errors and also provides a basis for detecting procedural errors (faulty routing, etc.). The difficulty with using written message exchange for all data transfers when studying the manual staff processes is that insistence on this communication means distorts some of the manual processes, e.g., retrieve, especially from maps and displays.

5.3.3 Temporary Displays.

Although only a limited class of data exchanges within the manual staff module employ temporary displays (sitmaps, tote boards, etc.), this form of communication is extremely important. Displays are readily accessible sets of data that provide the most convenient and frequently used "buffers" for human memory. This very convenience, i.e., so little effort is required to effect a data transfer, also makes this medium share the properties of voice communication. Since displays are posted for maximum visibility by decision makers, it is not, in general, possible to control or record the decision maker's access to such data. Because they are temporary (usually grease pencil on acetate to facilitate update) there is no permanent record which would provide means for error detection. Finally, because of the ease

of access, displays give rise to the shunting phenomenon in the same way as voice communication.

5.3.4 Hard Copy Displays.

This medium of exchange shares all of the properties of temporary displays except that a permanent record of the data transmitted is available. This property permits detection of data errors.

5.3.5 ADP Display.

The interposition of a computer terminal between the decision maker and the data base immediately overcomes the control and measurability deficiencies of displays. Not only can access be controlled, but a record can be kept of every transaction to include the duration of access. A permanent record of every transaction can be kept for error detection. The shunting phenomenon can be completely eliminated if the terminal is the only interface between the decision maker and the information system.

5.3.6 ADP Hard Copy.

The generation of hard copy by computer to substitute for written messages does not change any of the attributes of the written word insofar as control and measurement are concerned.

5.3.7 Summary.

The results of the above discussion of the impact of communication media on control and measurement are summarized in Table 5.9. The following conclusions are readily apparent:

- Because of the non-directional nature of data propagation by means of voice communication and displays, employment of these media is not amenable to control of access to the data base or to detection and measurement of access time. Similarly, because there is no permanent record of voice or temporary display transactions they are not amenable to data or procedural error detection. These same properties encourage the shunting phenomenon and make it virtually impossible to preclude it.

- Permanent displays share all of the above properties except that the permanent record does permit detection of errors.

- In contrast, written messages and computer displays and hard copy can be readily directed to designated

TABLE 5-9. IMPACT OF COMMUNICATION MEDIA ON MEASUREMENT AND CONTROL

COMMUNICATION MEDIUM	ACCESS TO DATA BASE CONTROLLED & MEASURABLE?	DURATION MEASURABLE?	ERROR MEASURABLE?	SHUNTING INHERENT?
Manual:				
Voice	No	No	No	Yes
Written Message	Yes	Yes	Yes	No
Temporary Display	No	No	No	Yes
Hard Copy Display	No	No	Yes	Yes
ADP:				
Display	Yes	Yes	Yes	No
Hard Copy	Yes	Yes	Yes	No

addressees and the accessing of data becomes a detectible and measurable property.

5.4 FACTORS AFFECTING TASK ASSIGNMENT

It is reasonably clear that the assignment of tasks to individual players will be determined by:

- The purpose of the investigation.
- The available labortory tool(s)--i.e., models and simulations.
- The staff system being emulated (manual, ADP-assisted, etc.).

Of these, the purpose of the investigation is clearly the driver or objective function and the last two serve as constraints. The discussion thus far in this section has largely been devoted to establishing a framework for examining the constraints imposed by the configuration of the simulation and the system being emulated. We shall now examine how experimental purpose affects task assignment and how such assignments may be constrained by considerations of tool and system.

5.4.1 Purpose of the Experiment.

We need first to consider a reasonably comprehensive classification of experimental purposes for which a model or simulation of this type might be used. Since we are talking about a combat simulation at the combined arms level in which are embedded one or more live staff modules which will be the subjects of the experiment, we are really talking about experiemnts which will examine the functioning of the military staff and how this affects the military decision making process. Since the purpose of the staff is to facilitate human decision making (para 5.1.1), one can say that the experimental purpose of such a tool, for behavioral research, is to examine the effectiveness of decision making as a function of a number of discrete independent variables. The following list is sufficiently comprehensive for our purpose since it seems to provide a category for all of the experiments that have been suggested. The purpose of such a tool is to examine decision making performance as a function of:

- The kind of data accessed.
- The quality of the data accessed.
- The performance of the individual processes.

- The data transfer medium.

- The time available for decision making.

- The personality of the decision maker.

Experiments involving the first five of these independent variables are examining the effect of changes in information system external to the decision maker on his decision making. The last turns the focus back onto the decision maker to see how decision making is affected by changes in the personality making the decision. In order to address the question of task assignment in experiments of these various types we need to examine each of these variables in greater detail to see exactly what kinds of experiments might be conducted.

5.4.2 Kinds of Behavioral Science Experiments.

The general classes of behavioral science experiments using a battle simulation may be further expanded as follows:

5.4.2.1 Data Requirement and Classification Experiments. (Investigations of the pertinence of information provided to and accessed by the decision maker(s).)

Such experiments seek to relate the effectiveness of the cognitive processes (as reflected in the simulated combat outcomes) with the substance of the information provided the decision maker. These experiments would include the following various conditions:

- All of the data normally generated by a combat environment are accessible (free access).

- The data normally generated are selectively denied (selected access).

- Since data are usually presented, not as individual data elements, but as data sets combining several data elements, the combination of data elements comprising a single data package can also be varied (data packaging).

5.4.2.2 Data Quality Experiments.

Such experiments seek to relate the effectiveness of the cognitive processes (as reflected in the simulated combat outcomes) to the quality of the data accessed by the decision maker. These experiments would include controlled changes in the following:

- Timeliness of the data provided (cognition/timeliness).

- Errors in the data provided (cognition/accuracy).

- Completeness of the data provided (cognition/completeness).

- False data provided (cognition/truth).

5.4.2.3 Process Performance Experiments.

These experiments measure human performance parameters for each of the elementary operations defined in para 3.1.1. Because of their differing effect on task assignment, one has to distinguish between such experiments for measuring lower level processes and those for the purpose of measuring cognitive processes. One can thus distinguish between experiments designed to measure.

- Processing times and delays in carrying out lower level processes (process/delay).

- Errors, both data and processing, in carrying out lower level processes (process/error).

- Omissions in carrying out lower level processes (process/omissions).

- Sequence of carrying out lower level processes (process/sequence).

- Processing times and delays in carrying out cognitive processes (cognition/delay).

- Errors in carrying out cognitive processes (cognition/errors).

- Omissions in carrying out cognitive processes (cognition/omissions).

5.4.2.4 Data Transfer Experiments.

These experiments seek to establish the relation between the nature of the data transfer medium between the decision maker and the data base and the effectiveness of his cognitive process as measured by the outcomes of simulated combat. They can also seek to relate the transfer medium to the performance parameters of the cognitive processes. Such experiments are of two types:

- Media that prevent shunting (controlled transfer).

- Media that permit shunting (shunting transfer).

5.4.2.5 Constrained Time Experiments.

Such experiments seek to observe the changes in process performance and/or combat outcome as a function of the time available for decision making. This is the most common means of imposing stress on decision makers and information processors.

5.4.2.6 Personality Experiments.

Such experiments could seek to observe changes in process and cognition performance as well as combat outcomes as a result of changing the staff persons to reflect controlled changes in intelligence, background, experience, personality, etc.

5.4.3 Experiments and Variables.

5.4.3.1 Reclassification.

Before proceeding to the next development, it is important to note that the classification of experiments listed above is somewhat redundant from the point of view of identifying task design requirements. For example, data requirements, data organization, and controlled transfer medium experiments all impose the same requirements on those variables affected by configuration and task design and none can be performed in any configuration that permits shunting. Let us, therefore, redefine four classes of experiment that encompass all nine of the classes listed above. These are:

- Data Accession Experiments. This class includes requirements, data organization, and controlled transfer experiments.

- Lower Level Process Experiments. This includes process experiments as described in para 5.4.2.3 as well as those time constrained and personnel experiments whose purpose is to measure lower level process performance as a result of changes in those independent variables.

- Cognition Experiments. This class includes the classes previously identified as cognition performance, data quality, as well as those time constrained and personality experiments whose purpose is measurement of effect on cognition (and battle outcome).

• Shunting Transfer Experiments. This is the only one of the original nine classes that remains unique in that it amounts to an effort to study cognition processes utilizing the manual mode data transfer media that permit shunting. It, therefore, precludes utilizing Configurations E, F, and E[1].

5.4.3.2 Variables.

The next step in the development of principles of task assignment is to examine the various kinds of experiments described above in terms of the variables that can be manipulated or measured in this kind of combat simulation. Such an examination can be made with the aid of the matrix shown at Table 5-10. Listed as column headings in the matrix are the manipulable and measurable variables. These are subdivided into those variables which should be completely determined by the experimental design and those which are determined by the combination of configuration selected and the task assignment. Listed as row headings on the left are the classes of experiments identified in para 5.4.2. The entries in the matrix indicate whether the variable in question is a potential independent variable (I), a variable that must be controlled (C), or a potential and measurable dependent variable (D), i.e., output. The word "potential" is used in the preceding sentence to indicate that all possible independent and dependent variables have been identified. They would not, in general, all be used in the same experiment. For example, the four basic characteristics of the input data would not all be varied simultaneously for data quality experiments. Similarly, for process performance experiments, one might not need to measure all of the process, cognition and combat output variables potentially available as outputs.

In addition to these entries the entry "NA" appears in a few cases where the variable is inappropriate. For example, in experiments which try to measure the cognition processes it is clearly not possible to utilize shunting transfers of data between the information system and the decision maker. Similarly, for experiments which do invoke the shunting phenomenon, controlled transfer is clearly inappropriate. The footnotes also specify output measurements which are precluded when shunting data transfers are permitted.

5.4.4 Task Design Requirements

The analysis has now reached the point where we can identify, for all possible combinations of configuration and class of experiment, which variables require modification of the SOP task description. This may be needed either for the purpose of controlling the variable or for measuring its value if it is needed as an output. The next series of tables identify such variables for each of the four classes of experiments defined above.

TABLE 5-10. EXPERIMENT CLASS VS SIMULATION VARIABLES

CLASS OF EXPERIMENT	SIMULATION VARIABLES																			
	FIXED BY EXPERIMENTAL DESIGN											CONTROLLED BY CONFIGURATION AND/OR TASK DESIGN								
	INPUT DATA							TSF MEDIUM				PROCESS					COGNITION			
	Content	Data Base Organization	Timeliness	Accuracy	Completeness	Truth	Change Rate	Controlled	Shunting	Decision Time	Personality	Delay	Error Rate	Omissions	Sequence	Accession Frequency	Delay	Error Rate	Omissions	Combat Outcomes
DATA ACCESSION	I	I	C	C	C	C	C	C	NA	C	C	C	C	C	C	D	D	D	D	D
LOWER LEVEL PROCESS	C	C	C	C	C	C	I	C	C[1]	I	I	D	D	D	D	D[1]	D[1]	D[1]	D[1]	D
COGNITION	C	I	C	C	C	C	I	I	NA	I	I	C	C	C	C	D	D	D	D	D
SHUNTING TRANSFER	C	C	C	C	C	C	I	NA[2]	I	I	I	C	C	C	C	[2]	[2]	[2]	[2]	[2]

1 If shunting permitted these variables are not measurable.

2 Since shunting permitted these variables are not measurable.

LEGEND:

I - Independent
C - Controlled
D - Dependent
NA - Not Applicable

5.4.4.1 Data Accession Experiments.

Table 5-11 shows the results of examining each configuration that can be used for this class of experiment to determine which variables (of those affected by configuration and task design) need to be additionally constrained by means of the task design. Listed across the top are the nine variables affected by configuration choice and task design. These are further identified as to whether they are variables to be controlled in this class of experiment or whether they are potential output variables to be measured. Shown as row headings at the left are the seven configurations previously defined. Entries for the first four of the configurations (A through D) are blank since these are the configurations which permit shunting and are, therefore, unusable for measuring data access. The table indicates that for configurations E and E[1] (all lower level processing within the simulation and the decision maker presumably communicates with the data base through a terminal) the simulation itself imposes all of the needed constraints on the controlled variables and provides the means necessary for all required measurements. Configuration F (ADP-assisted but with some manual lower level processing), on the other hand, does require additional constraints on the lower level processing variables. The simulation clearly provides the needed control on those lower level processes which are automated, but such controls are not present wherever there is a person-to-person data transfer. For such transfers the SOP task description must be augmented to provide for:

- Recording the time of receipt of the action and time of initiation of processing (to account for both time spent in queue and in process).

- Retaining a hard copy of the data in order to control error rates and omissions.

- Identifying the person handling the transaction in order to determine the sequence used in processing.

Furthermore, to insure that such lower level processing as is still carried out by people does not unduly degrade the data input, such persons should meet minimum performance standards (P. Std.) for process time, error rate, rate of omissions, and rate of making mistakes in sequencing (procedure). On the other hand, since the decision maker is presumably accessing the data base solely through a computer terminal, all of his cognition variables are directly measurable by the simulation and no additional task assignments over those required by the operating SOP need be imposed.

TABLE 5-11. CONFIGURATION TASK ASSIGNMENTS FOR DATA ACCESSION EXPERIMENTS

	PROCESS					COGNITION			
	DELAY	ERROR RATE	OMISSIONS	SEQUENCE	ACCESSION FREQUENCY	DELAY	ERROR RATE	OMISSIONS	COMBAT OUTCOME
CONFIGURATION	(Control)	(Control)	(Control)	(Control)	(Measure)	(Measure)	(Measure)	(Measure)	(Measure)
A	--	--	--	--	--	--	--	--	--
B	--	--	--	--	--	--	--	--	--
C	--	--	--	--	--	--	--	--	--
D	--	--	--	--	--	--	--	--	--
E	SIM	SIM	SIM	SIM	SIM	SIM	SIM	SIM	SIM
F	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM	SIM	SIM	SIM	SIM
E[1]	SIM	SIM	SIM	SIM	SIM	SIM	SIM	SIM	SIM

5.4.4.2 Lower Level Process Experiments.

Table 5-12 shows the results of a similar analysis of the lower level process experiments. For such applications Configurations E and E' are inapplicable by definition since they provide that all lower level processing be done within the simulation and not by the populated module. Configuration A provides that all processing be done manually so the simulation in itself provides no controls on any of these variables except that it does provide combat outcomes with no modification of the SOP task assignments. On the other hand, the task assignment must again provide for means to measure process timing, error rates, omissions, and sequence as in the case of the data accession experiments. For this class of experiments, these variables are to be measured and, therefore, no performance standard need be imposed; the purpose is to measure, not control, human performance. None of the cognition variables or frequency of data accession can be measured in this configuration for reasons explored at length in para 5.2. Combat outcome is, of course, measurable by the simulation itself.

Configurations B, C, and D are similar in that they progressively eliminate more and more manual processes from the populated module and move them "behind the curtain" into the simulation. The simulation itself can now provide the means to measure human performance at the interface between the simulation and man, but for the man-to-man exchanges the task assignment must still include means for measuring receipt and initiation times, for retaining hard copy, and for identifying operators. The other difference between these configurations and Configuration A is that these configurations permit measurement of cognition errors and omissions (should that be desired) by modifying the task assignment to insure that all displays are made on permanent copy.

The same considerations also apply to the first four process variables in Configuration F assuming that the manual processing in the system being emulated includes at least some man-to-man exchanges. Since the decision maker's interface with the simulation is presumably a computer terminal, the simulation take care of cognition performance measurements.

5.4.4.3 Cognition Experiments.

This class of experiments can conceivably be conducted with all seven configurations, although in the case of Configuration A the only cognition measurement possible is combat outcome. This is displayed in Table 5-13. For these experiments, the lower level processes need to be controlled in order to insure a reasonably standard quality data base as a basis for the cognition measurements. Therefore, the task assignments for Configurations A through D must provide for means

TABLE 5-12. CONFIGURATION TASK ASSIGNMENTS FOR LOWER LEVEL PROCESS EXPERIMENTS

	PROCESS					COGNITION			
	DELAY	ERROR RATE	OMISSIONS	SEQUENCE	ACCESSION FREQUENCY	DELAY	ERROR RATE	OMISSIONS	COMBAT OUTCOME
CONFIGURATION	(Control)	(Control)	(Control)	(Control)	(Measure)	(Measure)	(Measure)	(Measure)	(Measure)
A	TA	TA	TA	TA	NA	NA	NA	NA	SIM
B	SIM TA	SIM TA	SIM TA	SIM TA	NA	NA	TA	TA	SIM
C	SIM TA	SIM TA	SIM TA	SIM TA	NA	NA	TA	TA	SIM
D	SIM TA	SIM TA	SIM TA	SIM TA	NA	NA	TA	TA	SIM
E	—	—	—	—	—	—	—	—	—
F	SIM TA	SIM TA	SIM TA	SIM TA	SIM	SIM	SIM	SIM	SIM
E[1]	—	—	—	—	—	—	—	—	—

TABLE 5-13. CONFIGURATION TASK ASSIGNMENTS FOR COGNITION EXPERIMENTS

	PROCESS					COGNITION			
	DELAY	ERROR RATE	OMISSIONS	SEQUENCE	ACCESSION FREQUENCY	DELAY	ERROR RATE	OMISSIONS	COMBAT OUTCOME
CONFIGURATION	(Control)	(Control)	(Control)	(Control)	(Measure)	(Measure)	(Measure)	(Measure)	(Measure)
A	TA P.STD.	TA P.STD.	TA P.STD.	TA P.STD.	NA	NA	NA	NA	SIM
B	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	NA	NA	TA	TA	SIM
C	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	NA	NA	TA	TA	SIM
D	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	NA	NA	TA	TA	SIM
E	SIM	SIM	SIM	SIM	SIM	SIM	SIM	SIM	SIM
F	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM	SIM	SIM	SIM	SIM
E'	SIM	SIM	SIM	SIM	SIM	SIM	SIM	SIM	SIM

of timing lower level operations, hard copy as a standard of comparison, and identification of individuals to insure proper assignment of tasks. This provides the means to insure that specified standards of performance in carrying out lower level processes have been achieved. Specifying minimum performance standards for these lower level processes will also assist in achieving a standard data base. For Configurations B through C the simulation will impose the needed control for those processes moved back into the simulation. It will also be noted that, for these three configurations, cognition errors and omissions are measurable if the task assignment provides for hard copy displays. All of the cognition variables and accession frequency can only be measured for the last three configurations all of which provide for a computer terminal interface with the decision maker.

5.4.4.4 Shunting Transfer Experiments.

This is the class of experiments that might be termed "trying to define the undefinable," i.e., one is actually trying to study the lower level process/cognition process interface with an inadequate tool. In fact, it is this very property that makes these manual configurations inadequate for the data accession measurements that one is attmepting to study. As indicated in Table 5-14 Configurations E, F, and E' are, therefore, not usable for this purpose in that a computer terminal eliminates shunting. Otherwise, the same considerations that applied to Configurations A through D for cognition experiments also apply for shunting transfer.

5.5 PROCEDURE

As pointed out in the introduction to this section (para 5.0), the purpose of this development is to define the changes and/or additions that may be required to a specified SOP for the system to be emulated in order to insure that the required variables are controlled or measurable. It is assumed that such SOP is a part of the detailed system description. The following discussion, therefore, includes only a listing of the minimum contents of an SOP and concentrates on the special additional task assignments that must be imposed in order to establish control and measurability of the needed variables.

5.5.1 Standard Operating Procedure (SOP).

The SOP for the system being emulated must, as a minimum, contain the following elements although the SOP need not be packaged in this implied format:

- Roster of Personnel and Equipment. This includes a listing of all personnel (usually by MOS and grade) comprising a normal 12-hour shift and a listing of all equipment. In the manual mode (Configurations A

TABLE 5-14. CONFIGURATION TASK ASSIGNMENTS FOR SHUNTING TRANSFER EXPERIMENTS

	PROCESS					COGNITION			
	DELAY	ERROR RATE	OMISSIONS	SEQUENCE	ACCESSION FREQUENCY	DELAY	ERROR RATE	OMISSIONS	COMBAT OUTCOME
CONFIGURATION	(Control)	(Control)	(Control)	(Control)	(Measure)	(Measure)	(Measure)	(Measure)	(Measure)
A	TA P.STD.	TA P.STD.	TA P.STD.	TA P.STD.	NA	NA	NA	NA	SIM
B	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	NA	NA	TA	TA	SIM
C	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	NA	NA	TA	TA	SIM
D	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	SIM TA P.STD.	NA	NA	TA	TA	SIM
E	—	—	—	—	—	—	—	—	—
F	—	—	—	—	—	—	—	—	—
E[1]	—	—	—	—	—	—	—	—	—

through D) this includes such seemingly trivial equipment such as pencils, grease pencils, acetate, tracing paper, chairs and tables, as well as all communication terminals, duplicating machines, etc.

- Module Layout. This is a plan view of the physical layout of the staff module, drawn to scale, and identifying the location of every work station and the normal placement of personnel.

- List of Actions. This is a list of every transaction type that will be processed or generated by the staff module.

- List of Elementary Operations. This is a listing of every manual data processing operation that will be carried out in processing all action types listed, to include manual interface processes.

- Assignment of Elementary Operations. This is a designation of which staff members will normally perform each of the identified elementary operations and which members are authorized to perform them. For example, the SOP may authorize everyone to answer the telephone, only the operations sergeant and S-3 to update the SITMAP, and only the S-3 to release an order to subordinate commands.

- Sequence of Elementary Operations. This is an indication, usually in flow chart form, of the sequence in which the operations are normally performed for every action type to be processed.

- Schedule of Periodic Actions. This is a listing of the times at which each periodic action is to be initiated and submitted.

It will be noted that the above requirements are somewhat more detailed than SOPs prepared by most tactical units in the field. Nevertheless, such a detailed SOP exists in the minds of knowledgeable and experienced operations sergeants and must be made explicit and adhered to if the required degree of control is to be established over the process variables in manual staffs. For an ADP-assisted module, such an SOP becomes simpler and less voluminous as more and more elementary operations are performed by the computer and the SOP becomes more nearly a set of terminal operating instructions.

5.5.2 Modifying the SOP.

Having acquired and fleshed out, as necessary, the SOP for the system being emulated, the following series of steps will determine the modifications and augmentations needed to perform the desired experiment.

5.5.2.1 Class of Experiment.

Determine into which of the four experimental classes the desired experiment falls (data accession, lower level process, cognition, or shunting transfer as defined in para 5.4.3). Table 5-10 will be useful for this purpose since it identifies the potential independent and dependent variables for each class.

5.5.2.2 Configuration.

The next step is to choose, from those available, the configuration which most nearly meets the purposes of the experiment. This can be done with the aid of Tables 5-11 through 5-14 selecting the table appropriate for the class of experiment. For example, if one wanted to collect performance data for the lower level processes in an ADP-assisted mode, one must select Configuration F. If, on the other hand, one wanted to collect such data on a manual system one would have to select from A through D depending on which lower level processes one wanted data for. In general, one would select that configuration with the fewest lower level processes within the staff module in order to reduce the scope of the control problem (as well as cost).

5.5.2.3 SOP Modification.

The next and last step is to modify the SOP to facilitate control or measurement, as appropriate, of those variables for which controls must be imposed on the players. To determine this, refer to the appropriate table (5-11 through 5-14) for the class of experiment and select the row corresponding to the configuration selected. Appropriate revision must now be made to the SOP to control every variable which has an entry of TA. In general, this applies to the process variables for all manual processing which consists of two or more consecutive, manual processes. This includes Configuration F, and ADP-assisted case. If the speed, accuracy, completeness, and sequencing of such processes is to be controlled, their values must be measured. This requires recording of the time of transfer (completion) and time of initiation of every manually performed lower level process. Means which interfere minimally with the normal processing should be selected. For example, recording clocks mounted at all appropriate work stations can be used to record such times on every written data exchange. The same time clock can also record an identifer

for the operator performing that process. Finally, the SOP must be modified to provide for limiting data exchanges to hard copy if the error rate and omission rate are to be measured and controlled. There is one other class of SOP changes that must be incorporated if error rates and omissions are to be measured for the cognitive processes utilizing one of the manual configurations. This involves modifying the SOP for all visible files and displays accessed by the decision maker to insure that a permanent copy is made of all updates to those files. Only in this way can a reference standard be maintained for measurement of errors and omissions in the course of this processing. If the appropriate table also has an entry of P. Std. for a particular variable (limited to the lower level process variables) one must also select personnel who have passed some minimum standard of performance of these lower level processes in order to have some control over the delays and errors introduced into the section data base actually accesssed by the decision maker. These performance levels must be determined from the degree of data base degradation that can be tolerated for a particular experiment.

APPENDIX A

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